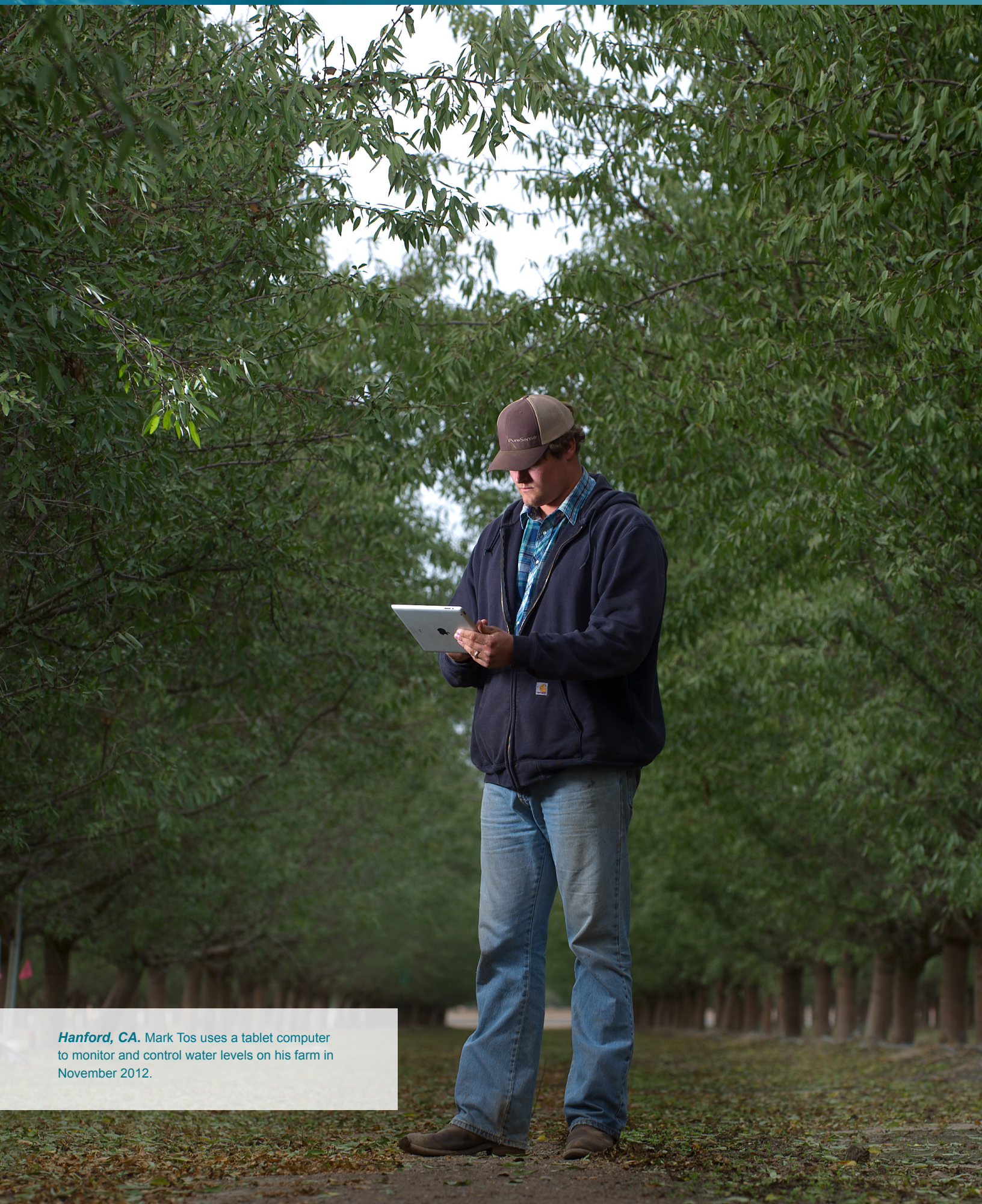
VOLUME 3 - RESOURCE MANAGEMENT STRATEGIES

CHAPTER 2

Agricultural Water Use Efficiency



Hanford, CA. Mark Tos uses a tablet computer to monitor and control water levels on his farm in November 2012.

Contents

Chapter 2. Agricultural Water Use Efficiency.....2-5
Agricultural Water Use Efficiency Efforts in California.....2-7
Agricultural Water Measurement.....2-10
Agricultural Water Management Planning.....2-12
Methodology for Quantification of Efficiency of Agricultural Water Use.....2-15
Efficient Water Management Practices.....2-18
Potential Benefits and Costs.....2-25
Water Supplier Water Use Efficiency.....2-29
On-Farm Water Use Efficiency.....2-30
Major Implementation Issues.....2-30
Funding.....2-30
Implementation.....2-32
Energy and Water Relationship.....2-33
Climate Change.....2-33
Education and Training.....2-34
Dry-Year Considerations.....2-35
Recommendations.....2-35
Implementation.....2-35
Data Measurement and Evaluation.....2-36
Education and Training.....2-37
Dry-Year Considerations.....2-37
Department of Water Resources' Near-Term Core Programs.....2-38
References.....2-38
References Cited.....2-38
Additional References.....2-40

Tables

Table 2-1 Trends in Irrigation Method Area (in million acres).....2-23
Table 2-2 On-Farm and Water Supplier Recoverable and Irrecoverable Flow Reductions.....2-27
Table 2-3 Projects Funded through Water Use Efficiency Grant Cycles Since 2001.....2-31

Figures

Figure 2-1 AB 1404 vs. SB X7-7.....2-12
Figure 2-2 Acres of Irrigated Agricultural Land by Irrigation Method in California in 2010.....2-21
Figure 2-3 Change in Irrigation Methods in California (1977-2010).....2-21
Figure 2-4 Statewide Trends in Irrigation Method Area from 1991 to 2011.....2-22
Figure 2-5 Regional Trends in Irrigation Method Areas.....2-24
Figure 2-6 Average and Incremental Cost per AF of Irrecoverable Loss Reduction.....2-28

Boxes

Box 2-1 Net Water Savings and Applied Water Reduction 2-6
Box 2-2 Agricultural Efficient Water Management Practices (EWMPs)*.....2-9
Box 2-3 SB X7-7 Agricultural Water Use Efficiency DWR Mandates* 2-11
Box 2-4 Required Elements of an Agricultural Water Management Plan (AWMP)* 2-13
Box 2-5 Regulated Deficit Irrigation 2-25
Box 2-6 Interrelation between On-farm and Regional Efficiencies and Role of Water Reuse 2-32

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 use to achieve a beneficial outcome. It includes an estimation of net water savings or increased production resulting from implementing efficiency measures as expressed by the ratio of output to input, resulting benefits, and strategies to achieve efficiency and benefits.

Water conservation is defined by California Water Code (CWC) Section 10817 as "the efficient management of water resources for beneficial uses, preventing waste, or accomplishing additional benefits with the same amount of water." Improvements in agricultural water use efficiency are expressed as yield improvements for a given unit amount of water, and can be estimated over individual fields or entire regions. The net water savings is the reduction in the amount of water applied that becomes available for other purposes, while maintaining or improving crop yield and agricultural productivity. Net water savings (see Box 2-1) 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.
3. The quantity of irrecoverable applied water that flows to salt sinks, such as the ocean and inaccessible or degraded saline aquifers, or that evaporates to the atmosphere and is unavailable for reuse.

Agricultural water use efficiency can be expressed as fractions that are the ratio of outputs from an agricultural system to inputs to that agricultural system in volumes or depths of water. A ratio of selected outputs (crop evapotranspiration [ET], crop agronomic use, and environmental water use) to inputs (applied water) can be used to quantify the efficiency of water use. This concept is discussed further in the section "Methodology for Quantification of Efficiency of Agricultural Water Use," below."

While inputs (rainfall and irrigation water) can readily be estimated and measured respectively, determining the amount of water required by the crop is a more complex undertaking. Crop water requirements during various growth stages have been modeled for most common crops. The models, however, assume an absence of typical real-world problems that are difficult to take into account such as diseases, insect infestations, and lack of uniform soils. As a result, models typically overestimate actual crop water requirements. Nevertheless, when used correctly, these models have provided valuable information in the past for better decision-making by farmers and irrigation districts. Recent approaches to estimating crop water requirements employ satellite imagery, often in conjunction with local weather stations, to estimate crop transpiration on a 30x30-meter grid of cells. The finer the grid, the better the accounting for the spatial non-uniformity of crop water use. Spatial non-uniformity of crop ET can be the result of many factors such as spatial variability of soil hydraulic characteristics, variability of field conditions, irrigation system non-uniformity, wheel traffic compaction, variability in farmers' cultural practices (e.g., pesticide and fertilizer applications), and varying effects of different populations of insects, nematodes, and denitrifying bacteria.

Box 2-1 Net Water Savings and 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. 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 going to salt sinks. 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. Much of recoverable flows in California go to wetlands and managed wetlands and provide the only source of water for sustainability of such wetlands. Reuse of applied water is the main reason why the quantity of saved water in the agricultural setting 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.

Agricultural water use efficiency aims at providing increased productivity and may result in water savings. Other co-benefits may include water quality improvements, environmental benefits, improved flow and timing, and often increased energy efficiency. While pursuing efficiency in agricultural water use, it is important not to isolate farming and the agricultural operations from their environment. With a holistic view, agricultural water use efficiency efforts must go beyond the simplistic irrigation efficiency approach to embrace a management approach that addresses the co-benefits of water use in agriculture. Such approach aims at ensuring a sustainable food production while protecting and restoring the natural and human environments. Being more efficient in some circumstances may mean greater costs and more energy use. Thus, third party impacts should be fully considered before mandating any significant water conservation or efficiency measures.

Agricultural water use efficiency does not necessarily mean a reduction in the amount of water used to grow crops. Often, increased water use efficiency — along with other management practices — allow for an increase in crop yield without increasing the amount of irrigation water. For the same amount of water used, an increase in crop yield translates into increased water productivity. In addition to advances in irrigation technology and improvements in water management, crop yield and water productivity can also be enhanced through fertilizer technology, crop selection, and scientific advancement in the domain of genetically modified (GMO) crop breeding.

The strategy to achieve improved agricultural water use efficiency primarily includes improvements in technology and management of water at different scales — on farms, at the irrigation district level, and at the regional scale. The strategy enlists an array of factors, such as labor, crop market conditions, demographics, education, changes in government policies, funding availability, environmental stresses, desire to increase yield, grower awareness and practices, energy, water supply development, water delivery systems, legal issues, economics, and land use issues.

A list of best management practices (other than irrigation technology and management of water) that contribute to agricultural water use efficiency is included in Chapter 21, “Agricultural Land Stewardship.” Chapter 21 includes a discussion of 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. According to a 2012 report of the California Department of Food and Agriculture, the state's 81,700 farms and ranches received a record $37.5 billion for their output in 2010, 1 percent more than the previous record achieved in 2008. California remained the No. 1 state in cash farm receipts in 2010, with its $37.5 billion in revenue representing 11.9 percent of the U.S. total. The state accounted for 16 percent of national receipts for crops and 7 percent of the U.S. revenue for livestock and livestock products. California's agricultural abundance includes more than 400 commodities. The state produces nearly half of the fruits, nuts, and vegetables grown in the United States. California's agricultural international exports broke a record in 2010, with $14.7 billion in value. It is estimated that every $1 billion in agricultural exports supports 8,400 jobs (U.S. Senate Committee on Agriculture, Nutrition, and Forestry 2012). The California Department of Water Resources (DWR) estimated that 2010 irrigated acreage was 8.13 million acres. The irrigated acreage changes from year to year. Agricultural water application varies significantly by year, depending on drought conditions. In a typical year, agriculture will irrigate about 9.6 million acres with 34 million acre-feet (maf) of water, or about one-third of the available surface water supplies (California Department of Water Resources Agricultural Water Use 2012a).

During the past 43 years, California growers and water suppliers improved water delivery systems and on-farm water management practices to increase agricultural production and conserve water. They switched many acres to higher-value crops and increased their crop yields. As a result, the economic value of the agricultural production per acre-foot (af) of water applied has greatly increased. The real inflation-adjusted total gross revenue for California agriculture increased by 86.5 percent between 1967 and 2010, from about $20.3 billion to $37.9 billion (both values are in 2010 dollars). During that period, the total water applied to crops was reduced by 5.1 percent, from about 31.2 maf in 1967 to 29.6 maf in 2010. As a result, the "economic efficiency" of agricultural water use has increased 96.6 percent during the same period, from $651/af of applied water (in 2010 dollars) in 1967, to $1,280/af in 2010. For information on how these estimates were derived, see the Volume 4 article, "Comparing Changes in Applied Water Use and the Real Gross Value of Output for California Agriculture: 1967 to 2010."

It is important, however, to note that the economic output of California agriculture, expressed either as crop yield or the dollar value of produced crops, is a function of many variables. These include water quality, soil fertility, fertilizer applications, insect infestation, plant diseases, cultural practices, management, crop selection, and crop variety, as well as many other physical, biological, and socioeconomic factors (such as crop market, trade and market conditions, and weather conditions). Given the complex factors affecting agricultural productivity, any economic output indicator can only be used as an overall gauge of the efficiency and competitiveness of California's agriculture and its agribusiness establishment in general and can by no means be linked exclusively to water use efficiency.

The Agricultural Water Suppliers Efficient Water Management Practices Act of 1990 (Assembly Bill [AB] 3616, CWC Sections 10900-10904) and the federal Central Valley Project Improvement Act (CVPIA) of 1992 established guidance for improving agricultural water use efficiency. Per AB 3616, the Agricultural Water Management Council (AWMC) was formed

through a memorandum of understanding (MOU) in 1996. Since its establishment and prior to its dissolution in 2013, the AWMC had enlisted close to 80 agricultural water suppliers and four environmental organizations to improve agricultural water use efficiency through the implementation of efficient water management practices. The AWMC worked in a voluntary and cooperative manner with agricultural water suppliers, environmental interest groups, government agencies, and other agricultural interest groups to establish a consistent endorsement process for agricultural water suppliers to demonstrate how they are managing water efficiently. Through a review and endorsement procedure, the AWMC helped with water suppliers' water management planning and the implementation of cost-effective, efficient water management practices and also tracked them. The signatory agricultural water suppliers voluntarily committed to implementing locally cost-effective management practices and submitted agricultural water management plans to the AWMC.

As part of a comprehensive package of water legislation in the 2009-2010 legislative session, the Agricultural Water Management Planning Act (AWMP Act), Part 2.8 of Senate Bill (SB) X7-7 requires agricultural water suppliers who provide water to 10,000 or more irrigated acres to develop and adopt a water management plan with specified components, and implement cost-effective efficient water management practices (EWMPs). However, any agricultural water supplier that provides water to less than 25,000 irrigated acres is exempt from implementing the bill's requirement unless sufficient funding has been provided to that water supplier to implement its provisions.

The bill also requires:

1. Agricultural water suppliers to submit their water management plan to DWR.
2. Agricultural water suppliers, on or before July 31, 2012, to implement EWMPs including the following critical EWMPs: 1) Measure the volume of water delivered to customers with sufficient accuracy to comply with provisions of the bill, and 2) Adopt a pricing structure for water customers based on at least in part on quantity of water delivered (see Box 2-2).
3. Agricultural water suppliers to use a standardized form to report which EWMPs 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. If an agricultural water supplier determines that an EWMP is not locally cost-effective or technically feasible, the supplier shall submit information documenting that determination.
4. DWR, in consultation with the State Water Resources Control Board (SWRCB), the California Bay-Delta Authority or its successor agency, the California 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.
5. DWR, in consultation with the SWRCB, to submit to the Legislature a report on the agricultural EWMPs that have been implemented, are planned to be implemented, and an assessment of the manner in which the implementation of those EWMPs has affected and will affect agricultural operations, including estimated water use efficiency improvements.
6. DWR to make available all submitted water management plans on the DWR Web site.
7. DWR, in consultation with the AWMC, academic experts, and other stakeholders, to develop a methodology for quantifying the efficiency of agricultural water use. Alternatives to be

Box 2-2 Agricultural Efficient Water Management Practices (EWMPs)*

The Agricultural Efficient Water Management Practices (EWMPs) per SB X7-7 include:

Critical EWMPs

- Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of California Water Code Section 531.10 and to implement EWMP #2.
- Adopt a pricing structure for water customers based at least in part on quantity delivered.

Other EWMPs

- Facilitate alternative land use for lands with exceptionally high-water duties or whose irrigation contributes to significant problems including drainage.
- Facilitate use of available recycled water that otherwise would not be used beneficially, meet all health and safety criteria, and do not harm crops or soils.
- Facilitate the financing of capital improvements for on-farm irrigation systems.
- Implement an incentive pricing structure that promotes one or more of the following goals:
  - More efficient water use at the farm level.
  - Conjunctive use of groundwater.
  - Appropriate increase of groundwater recharge.
  - Reduction in problem drainage.
  - Improved management of environmental resources.
  - Effective management of all water sources throughout the year by adjusting seasonal pricing structures based on current conditions.
- Expand line or pipe distribution systems, and construct regulatory reservoirs to increase distribution system flexibility and capacity, decrease maintenance, and reduce seepage.
- Increase flexibility in water ordering by, and delivery to, water customers within operational limits.
- Construct and operate supplier spill and tailwater recovery systems.
- Increase planned conjunctive use of surface water and groundwater within the supplier service area.
- Automate canal control structures.
- Facilitate or promote customer pump testing and evaluation.
- Designate a water conservation coordinator who will develop and implement the water management plan and prepare progress reports.
- Provide for the availability of water management services to water users. These services may include, but are not limited to, all of the following:
  - On-farm irrigation and drainage system evaluations.
  - Normal year and real-time irrigation scheduling and crop evapotranspiration information.
  - Surface water, groundwater, and drainage water quantity and quality data.
  - Agricultural water management educational programs and materials for farmers, staff, and the public.
- Evaluate the policies of agencies that provide the supplier with water to identify the potential for institutional changes to allow more flexible water deliveries and storage.
- Evaluate and improve the efficiencies of the supplier's pumps.

(*) These EWMPs may be updated by DWR as per SB X7-7, California Water Code Section10608.48(h).

assessed, shall include, but not be limited to, determination of efficiency levels based on crop types or irrigation system distribution uniformity.

The SB X7-7 requirements do not apply to an agricultural water supplier that is a party to the Quantification Settlement Agreement which allows the state to implement water conservation and transfer programs from the Colorado River, as defined in subdivision (a) of Section 1 of Chapter 617 of the Statutes of 2002, during the period within which the Quantification Settlement Agreement remains in effect (San Diego County Water Authority 2003). After the expiration of the Quantification Settlement Agreement, to the extent conservation water projects implemented as part of the Quantification Settlement Agreement remain in effect, the conserved water created as part of those projects shall be credited against the obligations of the agricultural water supplier pursuant to SB X7-7.

Box 2-3 lists SB X7-7 mandates related to agricultural water use efficiency and identifies DWR as the lead agency.

Agricultural Water Measurement

Lack of data, mainly farm-gate irrigation water delivery data, has been an obstacle for assessing irrigation efficiencies and planning further improvement. The State lacks comprehensive statewide data on cropped areas under various irrigation methods, 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 water use data to growers, water suppliers, and water resource planners are necessary for furthering water use efficiency. An identified concern 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 2003 Independent Panel on the Appropriate Measurement of Agricultural Water Use convened by California Bay-Delta Authority made specific recommendations for measuring water supplier diversions, net groundwater use, crop water consumption, and aggregate farm gate deliveries (Independent Panel on the Appropriate Measurement of Agricultural Water Use 2003). In addition, the panel recommended increasing efforts to measure water quality, return flows, and streamflow. As a result, AB 1404, Water Measurement Information, was signed into law in 2007, requiring agricultural water suppliers to submit water use measurement reports to DWR. Agricultural water suppliers providing 2,000 or more acre-feet of surface water annually for agricultural uses or serving 2,000 or more acres of agricultural lands are required to submit a report annually 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.

The passage of the SB X7-7 in 2009 required certain agricultural water suppliers (those providing water to 10,000 or more acres of irrigated land) to measure the water they deliver to their customers. This legislation also required DWR to adopt a regulation that sets criteria and accuracy standards for farm-gate measurement and reporting. This regulation provides a range of water measurement options that would allow agricultural water suppliers to implement the aforementioned critical EWMPs (measurement and volumetric pricing) and comply with the reporting of aggregate farm-gate water deliveries. All agricultural water suppliers serving more

Box 2-3 SB X7-7 Agricultural Water Use Efficiency DWR Mandates*

A1. Quantification of Efficiency of Agricultural Water Use (Section 10608.64).
The California Department of Water Resources (DWR), in consultation with the Agricultural Water Management Council (AWMC), stakeholders, and academics, shall develop and report to the Legislature on a proposed methodology for quantifying the efficiency of agricultural water use. The report is to include an implementation plan, estimated implementation costs and types of data to support the methodology. Alternatives shall include determination of efficiency levels based on crop type or irrigation system distribution uniformity.

A2. Agricultural Water Measurement Regulations (Section 10608.48(i)(1)).
DWR will adopt a regulation providing a range of options for water measurements that agricultural water suppliers may use to measure volume of water delivered to customers with sufficient accuracy to comply with the farm-gate delivery measurement requirement (531.10) and to implement pricing structure.

A3. Update Ag Efficient Water Management Practices (EWMPs) Section 10608.48(h)).
DWR may update the EWMPs in consultation with AWMC, US Bureau of Reclamation and SWRCB. EWMPs shall be adopted or revised only after public hearings.

A4. Ag EWMP Report to Legislature (Section 10608.48(g)).
DWR shall submit a report to the Legislature on agricultural EWMPs that have been and are planned to be implemented and an assessment of the manner in which the implementation of EWMP has affected and will affect agricultural operations an estimate of water use efficiency improvements. Subsequent reports will be prepared in 2016 and 2021.

A5. Ag Water Mgmt Plan Report to Legislature (Sections 10845(a) through (c)).
DWR shall prepare and submit to the Legislature a report summarizing the status of the submitted plans, their outstanding elements, effectiveness of promoting efficient ag practices and recommendations relating to proposed EWMP changes, as appropriate. The report will subsequently be submitted in years ending in six and one.

A6. AWMP Guidebook (Section 10608.50(a)(1)).
DWR, in consultation with the State Water Resources Control Board (SWRCB), may revise the requirements for AWMPs. An AWMP Guidebook will be developed to address legislative and procedural issues for submittal of AWMPs to DWR.

A7. Revise Ag Funding Criteria (Section 10608.56(b)).
DWR will develop grant/loan criteria to make agricultural water suppliers ineligible for state funding unless they comply with the specific provisions of 10608.56.

B1. Standardized Water Use Reporting (Sections 10608.52(a) and (b)).
DWR, in consultation with California Bay Delta Authority, California Department of Health, California Public Utilities Commission, and SWRCB, shall develop a single standardized water use reporting form to meet the water use information needs of each agency. The form will be used by urban water suppliers to report on their progress in meeting their targets (10608.40) on an individual or regional basis at a minimum and by agricultural water suppliers to report compliance with implementation of EWMPs.

B2. Promote Regional Water Management (Section 10608.50(a)).
DWR, in consultation with the board, shall promote implementation of regional water resources management practices through increased incentives and removal of barriers.

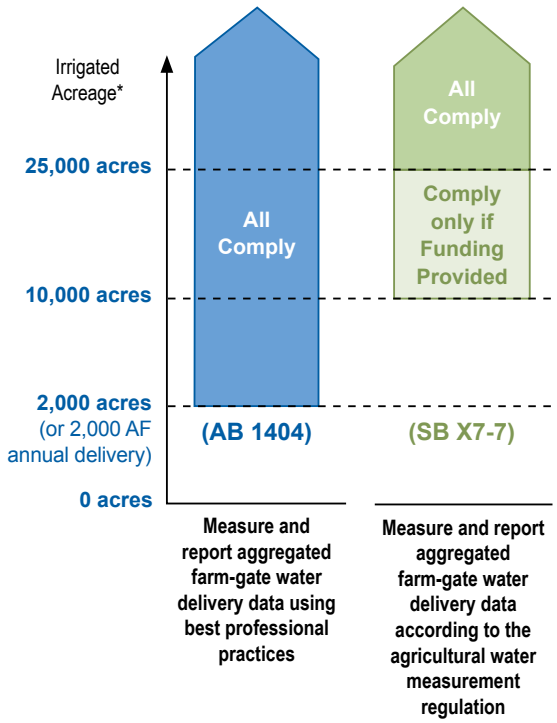
B3. Statewide Targets for Regional Practices (Section 10608.50(b)).
DWR shall propose new statewide targets or review and update existing statewide targets for regional water resources management practices including but not limited to recycled water, brackish groundwater desalination and infiltration and direct use of urban stormwater runoff. Updated targets should be included in the California Water Plan.

(*) B1-B3 are agricultural as well as urban projects.

than 2,000 acres or providing 2,000 acre-feet are subject to AB 1404, but only certain large agricultural water suppliers, those serving more than 25,000 acres or 10,000 acres if funding is provided and outside the Quantification Settlement Agreement (QSA), are also subject to SB X7-7. Suppliers subject to AB 1404 must measure using Best Professional Practices; suppliers subject to SB X7-7 must use the criteria and accuracy standards in Agricultural Water Measurement regulation (Title 23, Division 2 of the California Code of Regulations, Chapter 5.1, Sections 597, 597.1, 597.2, 597.3, and 597.4) (See Figure 2-1, which shows AB 1404 vs. SB X7-7 applicability.)

Figure 2-1 AB 1404 vs. SB X7-7

Relationship of Applicability of Agricultural Water Measurement Provisions



*Acres that receive only recycled water are excluded from SB X7-7 thresholds.

Subsequently, DWR convened an agricultural stakeholders committee (ASC) and a stakeholders' sub-committee focusing on water measurement. Based on input from the ASC, stakeholders, and the general public, DWR adopted an emergency agricultural water measurement regulation that went into effect in July 2011. DWR followed-up and developed a regulation through the rulemaking process. On July 2012, the Office of Administrative Law approved the Agricultural Water Measurement Regulation. The Regulation adds Sections 597 to 597.4 of the California Code of Regulations (CCR) Title 23, Division 2, Chapter 5.1. The process leading to the development and adoption of this regulation benefitted from the participation and input of various stakeholders, academic experts, and the general public. The process included several meetings of the ASC and its water measurement sub-committee, two public hearings, two listening sessions, a 45-day public comment period, and an additional six 15-day public comment periods.

Agricultural Water Management Planning

SB X7-7 Part 2.8 (AWMP Act) requires agricultural water suppliers that meet certain criteria must prepare an Agricultural Water Management Plan (AWMP). This act provided a list of required elements that must be included in the AWMP (see Box 2-4). CWC Section 10820 (a) states, "An agricultural water supplier shall prepare and adopt an agricultural water management plan in the manner set forth in this chapter on or before December 31, 2012, and shall update that plan on December 31, 2015, and on or before December 31 every five years thereafter." SB X7-7 defines an "Agricultural Water Supplier" as "a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding recycled water." "Agricultural

Box 2-4 Required Elements of an Agricultural Water Management Plan (AWMP)*

SB X7-7 (2009), California Water Code Section 10826, lists the required elements of an AWMP as follows:

1. Describe the agricultural water supplier and the service area, including all of the following:
   - A. Size of the service area.
   - B. Location of the service area and its water management facilities.
   - C. Terrain and soils.
   - D. Climate.
   - E. Operating rules and regulations.
   - F. Water delivery measurements or calculations.
   - G. Water rate schedules and billing.
   - H. Water shortage allocation policies.
2. Describe the quantity and quality of water resources of the agricultural water supplier, including all of the following:
   - A. Surface water supply.
   - B. Groundwater supply.
   - C. Other water supplies.
   - D. Source water quality monitoring practices.
   - E. Water uses within the agricultural water supplier's service area, including all of the following:
     - i. Agricultural.
     - ii. Environmental.
     - iii. Recreational.
     - iv. Municipal and industrial.
     - v. Groundwater recharge.
     - vi. Transfers and exchanges.
     - vii. Other water uses.
   - F. Drainage from the water supplier's service area.
   - G. Water accounting, including all of the following:
     - i. Quantifying the water supplier's water supplies.
     - ii. Tabulating water uses.
     - iii. Overall water budget.
   - H. Water supply reliability.
3. Include an analysis, based on available information, of the effect of climate change on future water supplies.
4. Describe previous water management activities.
5. Include in the plan the water use efficiency information required pursuant to CWC Section 10608.48.

(*) Additional elements may be required to be included in the AWMP to document compliance with the Agricultural Water Measurement Regulation (California Code of Regulations Title 23, Division 2, Chapter 5.1, Sections 597-597.4).

water supplier" includes a supplier or contractor for water, regardless of the basis of right that distributes or sells water for ultimate resale to customers" (CWC Section 10608.12).

CWC Section 10842 requires an agricultural water supplier to implement its adopted plan in accordance with the schedule set forth in the plan, as determined by the governing body of the agricultural water supplier. An agricultural water supplier is also required to submit a copy of its plan and amendments or changes to the plan to the following:

1. California Department of Water Resources.
2. Any city, county, or city and county in which the agricultural water supplier provides water supplies.
3. Any groundwater management entity in which jurisdiction the agricultural water supplier extracts or provides water supplies.
4. Any urban water supplier in which jurisdiction the agricultural water supplier provides water supplies.
5. Any city or county library in which jurisdiction the agricultural water supplier provides water supplies.
6. The California State Library.
7. Any local agency formation commission serving a county in which the agricultural water supplier provides water supplies.

Agricultural water suppliers providing water to equal or greater than 25,000 irrigated acres (and water supplier providing 10,000 to 25,000 acres if adequate funding is available), excluding recycled water are also affected by the AWMP Act. Agricultural water suppliers that submit water management plans in compliance with the U.S. Bureau of Reclamation (USBR) Central Valley Project Improvement Act (CVPIA) or the Reclamation Reform Act of 1982 (RRA) requirements may be able to submit those plans or modify those plans with additional information to satisfy SB X7-7 AWMP Act (CWC Section 10827).

CWC Section 10608.50(a)(1) mandated DWR, in consultation with the SWRCB, to promote implementing regional water resources management practices through increased incentives and removing barriers, consistent with state and federal law. Among the potential tasks enumerated by the Legislation are the revisions to the requirements for urban and agricultural water management plans. As a result, and to assist agricultural water suppliers in complying with the requirements of the AWMP Act, DWR developed an Agricultural Water Management Planning Guidebook in 2012. The guidebook is meant to help agricultural water suppliers better understand the SB X7-7 requirements and assist them in developing their AWMPs. The guidebook also provides information on how agricultural water suppliers may meet the requirements of the Agricultural Water Measurement Regulation and associated compliance documentation, as well as aggregated farm-gate delivery reporting format. The guidebook is available at http://www.water.ca.gov/wateruseefficiency/sb7/docs/AgWaterManagementPlanGuidebook-FINAL.pdf.

When applicable, an AWMP shall also include in addition to the required elements as specified by CWC Section 10820 (a), other elements such as documentation to show compliance with the Agricultural Water Measurement Regulation (CCR Title 23, Division 2, Chapter 5.1, Sections 597-597.4). The Agricultural Water Measurement Regulation requires specific documentation to demonstrate compliance. For example, if water cannot be measured at the farm-gate or delivery point, agricultural water suppliers that provide water to 25,000 irrigated acres or more must include certain agricultural water measurement documentation in their AWMP in accordance

with Agricultural Water Measurement Regulation (CCR Section 597.4(e)). Additionally, if an existing water measurement device is not compliant with the regulation and cannot be modified to be compliant, the AWMP must then include a schedule, budget, and finance plan for taking corrective action in three years or less (CCR Section 597.4(e)(4)). Agricultural water suppliers providing water to 10,000 to 25,000 irrigated acres who are required to prepare an AWMP may have to incorporate agricultural water measurement documentation in their AWMP if implementation of agricultural water measurement has been funded as specified in CCR Section 597.4(e).

Methodology for Quantification of Efficiency of Agricultural Water Use

The SB X7-7 directed DWR, in consultation with the AWMC, academic experts, and other stakeholders, to develop and report to the Legislature a proposed methodology for quantifying the efficiency of agricultural water use and an implementation plan that includes estimated implementation costs, roles and responsibilities, and the type of data needed to support the methodology. To carry out the mandate, DWR formed a second subcommittee of the ASC focusing on the quantification of agricultural water use efficiency. DWR held numerous public listening sessions, stakeholder committee and subcommittee meetings, and public workshops to develop the methodology and prepare a report to the Legislature, which was submitted in July 2012. The legislation did not authorize DWR to implement the methodology. However, DWR recommends that if the proposed methodology is authorized for implementation, the Legislature should appropriate the necessary funding to cover its implementation costs as described in its report to the Legislature.

To develop a methodology to quantify the agricultural water use efficiency, a water balance approach was considered to look into the various components of agriculture water use (environmental water use associated with irrigated lands). Other uses of water in agriculture — dairy production areas, washing products — are not included in the water balance because they represent small fractions of the total water use in most cases and are difficult to quantify. The methodology proposed is composed of four consistent and practical methods for quantifying the efficiency of water use by irrigated agriculture and are stated below. To develop the methods, DWR considered the components of a water balance at three spatial scales — basin, water supplier, and field — to understand and estimate through measurements or calculations how much water enters and leaves these areas. As a result, DWR proposed four methods for quantifying the efficiency of agricultural water use to help identify opportunities to improve the water use efficiency at different spatial scales. The methodology is suitable for evaluating current conditions and strategies for improving agricultural water management on the diverse array of agricultural irrigation systems and operations found throughout California. The anticipated users of these methods are farmers, water suppliers, basin water management groups, nongovernmental organizations, and local, state, federal, and tribal water planners.

The methods presented for quantifying the efficiency of agricultural water use are based on water use efficiency fractions that are a ratio of outputs from an agricultural system to an input to the agricultural system in volumes and/or depths of water. Input to an agricultural system is the volume of applied water. Outputs from agricultural systems include ET from crops, agronomic uses such as leaching salts, evaporation during seed germination, climate control (frost protection and cooling), environmental water use, tailwater, deep percolation, evaporation from open water surfaces, and ET by non-crops (weeds, for example). The ratio of selected outputs (crop ET, crop

agronomic use, and environmental water use) to inputs (applied water) is used to quantify the efficiency of water use. Other outputs (evaporation from soil or water surfaces in excess of ET, ET by non-crop vegetation, and flow to salt sinks, etc.) are not quantified and may be estimated in total as residual in the water balance. Crop ET, crop agronomic uses (leaching, evaporation during seed germination, evaporation for cooling or application for frost control), and evaporation and ET for environmental purposes are intended uses (outputs). Crop ET is generally estimated using theoretical or empirical models that assume field uniformity. Actual ET can be estimated from remotely sensed satellite imagery. Some remote sensing methods use an energy balance approach; others use a vegetation index approach that is calibrated to the crop coefficient; and others couple remotely sensed parameters with numerical models or point measurements to generate ET information.

Each of the four methods below evaluates a different portion (fraction) of applied water:

1. **Crop Consumptive Use Fraction (CCUF)**. This method evaluates the relationship (ratio) between the consumptive use of crop(s) and the quantity of water applied. CCUF is a fraction that shows the proportion of applied water that is consumed by the crop. It is applicable at the basin, water supplier, and field scales.

2. **Agronomic Water Use Fraction (AWUF)**. This method calculates the ratio of agronomic use (salinity management, germination, etc.) and consumptive uses of crop(s) to the quantity of water applied. AWUF is a fraction that shows the portion of applied water used to grow the crop including crop consumptive use and agronomical use. It is applicable at the basin, water supplier, and field scales.

3. **Total Water Use Fraction (TWUF)**. This method further expands on the CCUF and AWUF by evaluating the relationship (ratio) between water applied for crop consumptive use, crop agronomic use, and for environmental objectives and the quantity of applied water. TWUF accounts for all intended water uses. As a result, this fraction can be used as a measure of total water use efficiency. It is applicable at the basin, water supplier, and field scales.

4. **Water Management Fraction (WMF)**. This method evaluates the relationship between crop consumption use and recoverable flows and quantity of applied water. This method estimates the recoverable water available for reuse at another place or time in the system. It is applicable at the basin and water supplier scales and is not intended for field scale.

The DWR report to the Legislature on the proposed methodology included an implementation plan as well as the potential associated costs. The plan included a three-phase schedule of implementation and identified implementing entities, roles, data needs and sources, and data management. Implementing the methodology would require new funding for DWR and water suppliers. The cost to DWR to implement the proposed methodology is approximately $400,000 per year in addition to a one-time cost of $500,000 for developing a database. Estimated costs to water suppliers serving water to more than 25,000 acres or irrigated land (these suppliers account for approximately 6 million acres of irrigated land) would be about $6 to $30 million per year. Water measurement costs are excluded from this estimate, since water delivery measurement to fields is required by the CWC for these suppliers. Estimated costs to water suppliers serving water to more than 10,000 but less than 25,000 acres or irrigated land (these suppliers account for approximately 757,000 acres of irrigated land) would be about $8.8 million per year and a one-time cost of $15 million for installing water measurement devices.

In addition to the four methods for quantifying the efficiency of agricultural water use, DWR included four indicators in this report that would provide supplemental information about irrigation and delivery system performance and crop productivity. These indicators do not quantify the agricultural water use efficiency, but help estimate the limits of potential efficiency and productivity. Two of the indicators help describe the performance of the growers' irrigation system. These are distribution uniformity (DU) and delivery fraction (DF).

1. **Distribution Uniformity (DU)** is a measure of irrigation system performance—how evenly water is applied and infiltrates into the soil across a field during an irrigation event. It is not a measure of how efficiently water is used on the field. A well-designed irrigation system applies water to crops as uniformly as possible to optimize crop production. DU is applicable at the field scale. Under CWC Section 10608.48(c), many water suppliers may provide on-farm irrigation evaluation service, if locally cost effective, that include the determination of DU and other information of the irrigation system.

2. **Delivery Fraction (DF)** evaluates the relationship (ratio) between the water delivered to water supplier customers and the agricultural water supplier's water supply. It is applicable only at the water supplier scale. Under CWC Sections 531.10 and 10608.48, many water suppliers are required to determine and report aggregated farm-gate delivery and water supply. These are the components used to calculate delivery fraction.

The other two indicators help describe crop productivity (relationship of the volume of water applied to an area to the total crop yield and gross crop revenue) — Productivity of Applied Water (PAW) and Value of Applied Water (VAW).

3. **Productivity of Applied Water (PAW)** illustrates the relationship (ratio) between crop production in tonnage and the volume of applied water. It is most applicable at a statewide or county scale.

4. **Value of Applied Water (VAW)** illustrates the relationship (ratio) between gross crop value in dollars and the volume of applied water. It is most applicable at the statewide and county scales.

The crop productivity indicators provide information about the relationship and trends of crop yield and/or monetary value to the volume of irrigation water applied during production. They can indicate long-term changes or trends in agricultural production and income relative to applied water at larger spatial scales. However, these indicators neither quantify the efficiency of agricultural water use nor the economic efficiency. Crop production depends on many factors other than the water to meet crop consumptive and non-consumptive needs, including water quality, climate, soil type, soil depth, crop parameters (variety), crop management (fertilizer and pest management, etc.), and water management (irrigation system, irrigation management, and water supply flexibility and reliability). As a result, the crop productivity indicators should not be used to draw conclusions about regional crop selection because many factors other than applied water affect crop selection, crop production, and crop value.

The crop productivity indicators can be used to inform interregional comparisons of long-term averages of the amounts of water necessary to achieve competitive yields. However, long periods are needed to attain dependable averages. Additionally, the value of such comparisons will be limited by the inability to act on the information without unprecedented interference with the ability of growers to respond to price signals. Maximal crop yields are frequently not the most water efficient yields and yields do not decrease at a constant rate with decreasing irrigation.

As a result, the optimal economic yield per unit of water for a specific crop may not correspond to the maximal yields. In this regard, the crop productivity indicators can be used to produce comparisons of yields as a function of irrigation levels. Developing such models for various crops would be a significant contribution, one which may serve growers well as demands on the State's water supplies increase. Knowledge of optimal water efficient irrigation levels for various crops may increase the resilience of the agricultural sector when challenged by drought.

Efficient Water Management Practices

Pursuant to SB X7-7, certain agricultural water suppliers, as defined in CWC Section 10608.12, shall implement on or before July 31, 2012 two specific critical EWMPs. These are stated in CWC Section 10608.48(b):

1. Measure the volume of water delivered to customers with sufficient accuracy to comply with subdivision (a) of Section 531.10 and to implement paragraph (2).

2. Adopt a pricing structure for water customers based at least in part on quantity delivered.

Agricultural water suppliers have to implement 14 additional EWMPs if they are locally cost-effective and technically feasible (CWC Section 10608.48 (c)). The 16 EWMPs, as stated in SB X7-7, are listed in Box 2-2.

As part of the agricultural water use efficiency provisions, SB X7-7 states that DWR may update the EWMPs in consultation with the AWMC, USBR, and SWRCB (CWC Section 10608.48(h)). These EWMPs for agricultural water use shall be adopted or revised only after DWR conducts public hearings to allow participation by stakeholders from the diverse geographical areas and interests of the state. Planning for this task is underway. Also, CWC Section 10608.48(g) requires that DWR submit a report to the Legislature on agricultural EWMPs (implemented or planned) and an estimate of water use efficiency improvements on or before December 2013. Subsequent reports will be prepared in 2016 and 2021. Additionally, DWR shall also prepare and submit a report to the Legislature summarizing the status of the submitted Agricultural Water Management Plans, their outstanding elements, effectiveness of promoting EWMPs, and recommendations relating to proposed EWMPs changes as appropriate. Similar reports will be submitted subsequently in years ending in six and one (CWC Sections 10845(a) through (c)).

As part of their AWMPs, agricultural water suppliers also required to "Report on which efficient water management practices have been implemented and are planned to be implemented, an estimate of the water use efficiency improvements that have occurred since the last report, and an estimate of the water use efficiency improvements estimated to occur five to 10 years in the future. If an agricultural water supplier determines that an efficient water management practice is not locally cost effective or technically feasible, the supplier shall submit information documenting that determination" (CWC Section 10608.48 (d)).

Note that in addition to the EWMPs listed in Box 2-2, there are important farming cultural practices such as 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.

The State Water Resources Control Board and the Delta Stewardship Council published a report in 2011 that examines the "reasonable use doctrine" (i.e., the constitutional principle that forbids waste and mandates that state water resources be used reasonably and beneficially) as it relates to agricultural water use efficiency. The report, titled *The Reasonable Use Doctrine and Agricultural Water Use Efficiency*, addresses how the State's Reasonable Use Doctrine may be employed to promote more efficient water use in the agricultural sector. The report shows that there is a wide array of irrigation practices in place today that result in the more efficient and, therefore, a more reasonable use of water. The report concludes that the Reasonable Use Doctrine may be employed to promote a wider use of such efficient practices (Wilson 2011). The report recommends that the State Water Resources Control Board convene a Reasonable Water Use Summit and contain specific recommendations for consideration during the summit. The recommendations range from a wider employment of efficiency practices such as improvements to the irrigation systems that deliver water to farms, weather-based irrigation scheduling, and more efficient irrigation methods. The report is available at http://www.waterboards.ca.gov/board_info/agendas/2011/jan/011911_12_reasonableusedoctrine_v010611.pdf.

A report by the Pacific Institute, *California Farm Water Success Stories*, a follow-up to the Institute's 2009 report, identified and analyzed some successful case studies of sustainable agricultural water management policies and practices in California. The examples highlighted both on- and off- farm activities that led to more efficient applied water use or enhanced water quality, increased crop yields or quality, and provided multiple benefits. Such activities included planning and management practices, technological improvements, information dissemination, use of recycled water, and incentive and assistance programs (Christian-Smith et al. 2011).

In June 2011, the California Roundtable on Water and Food Supply issued a set of recommendations in a report entitled *Agricultural Water Stewardship: Recommendations to Optimize Outcomes for Specialty Crop Growers and the Public in California* that was addressed to state agencies, water suppliers, local water management groups, the agricultural community, and the research community. The California Roundtable is a forum of leaders in food production and water to uncover obstacles, identify strategic and widely accepted solutions, and generate recommendations to ensure a reliable, long-term supply of water to California's specialty crop producers while optimizing other beneficial uses of water. The Roundtable defines agricultural water stewardship as on-farm water use in a manner that optimizes beneficial uses of water and recognizes the co-benefits of water for food production and environmental and human health. Going further, the Roundtable identified agricultural water stewardship as a key area of importance for sound long-term water management. The specific recommendations center around three key solution themes with the goal of improving and promoting agricultural water stewardship:

1. Create a stronger knowledge base.
2. Improve support mechanisms for growers.
3. Move toward outcome-based policy and regulatory frameworks that foster agricultural water stewardship (California Roundtable on Water and Food Supply 2011).

The report is available at http://aginnovations.org/images/uploads/CRWFS_Water_Stewardship_Recs_electronic.pdf.

A July 2011 report prepared for the Northern California Water Association (NCWA), titled *Efficient Water Management for Regional Sustainability in the Sacramento Valley,* presented a framework for addressing agricultural water use efficiency in the Sacramento Valley while considering the Valley's hydrologic characteristics and existing conditions. The report outlined a technical framework to guide water use efficiency efforts in the Sacramento Valley by providing water resources managers with tools to identify, assess, and pursue specific water use efficiency opportunities while emphasizing the need for achieving regional sustainability. While recognizing that potential water use efficiency improvements have statewide as well as local and regional benefits, the report pointed out the challenge to Sacramento Valley water managers to develop coalitions within and outside the Valley to garner the necessary resources to advance water use efficiency for achieving regional sustainability and statewide benefits (Northern California Water Association 2011). The report is available at http://www.norcalwater.org/wp-content/uploads/2012/01/Technicalreport-jul2011.pdf.

Growers invest in on-farm water management improvements to stay economically competitive. Likewise, local water suppliers invest in cost-effective, systemwide water management improvements in order to provide quality service at a fair and competitive price. Substantial financial support for research, development, and the demonstration of efficient water management practices in agriculture comes from the agricultural industry, 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 investment in research, demonstration, and technical assistance for growers is critical, especially in support of university-based research, field station studies, Cooperative Extension demonstration projects, and technical assistance and outreach through Resource Conservation Districts.

Ways to Improve Agricultural Water Use Efficiency

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

1. Hardware — improving on-farm irrigation systems and water supplier delivery systems.
2. Water management — reducing non-beneficial ET and improving management of on-farm irrigation and water supplier delivery systems.
3. Agricultural technology — breeding, GMO crops, insect and disease control, fertilizers, technology, etc.

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, as shown in Figure 2-2 (sample percentages are based on voluntary survey responses).

Almost all trees and vines established since 1990 are irrigated using micro irrigation. Between 1991 and 2011, the crop area under micro irrigation in California grew from 1.26 million to 3.12

million acres, a 150 percent increase (see Figure 2-3 and Table 2-1).

A survey of more than 10,000 growers in California (excluding rice, double cropping, dry land, and livestock producers) was conducted by the DWR Land and Water Use program to investigate current trends in irrigation methods used statewide. Results from the survey indicate that the land acreage irrigated by low-volume irrigation methods (drip and micro sprinklers) has increased by 16 percent between 2001 and 2011, while the acreage of land irrigated by surface irrigation methods has decreased by 13 percent (Orang et al. 2011) See Figure 2-4.

Many growers use advanced irrigation systems for irrigation, fertilizer application, and pest management. Advanced technologies include

Figure 2-2 Acres of Irrigated Agricultural Land by Irrigation Method in California in 2010

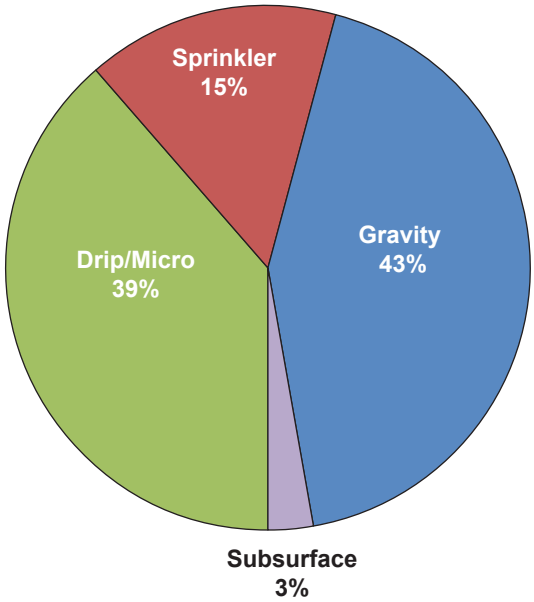


Figure 2-3 Change in Irrigation Methods in California (1977-2010)

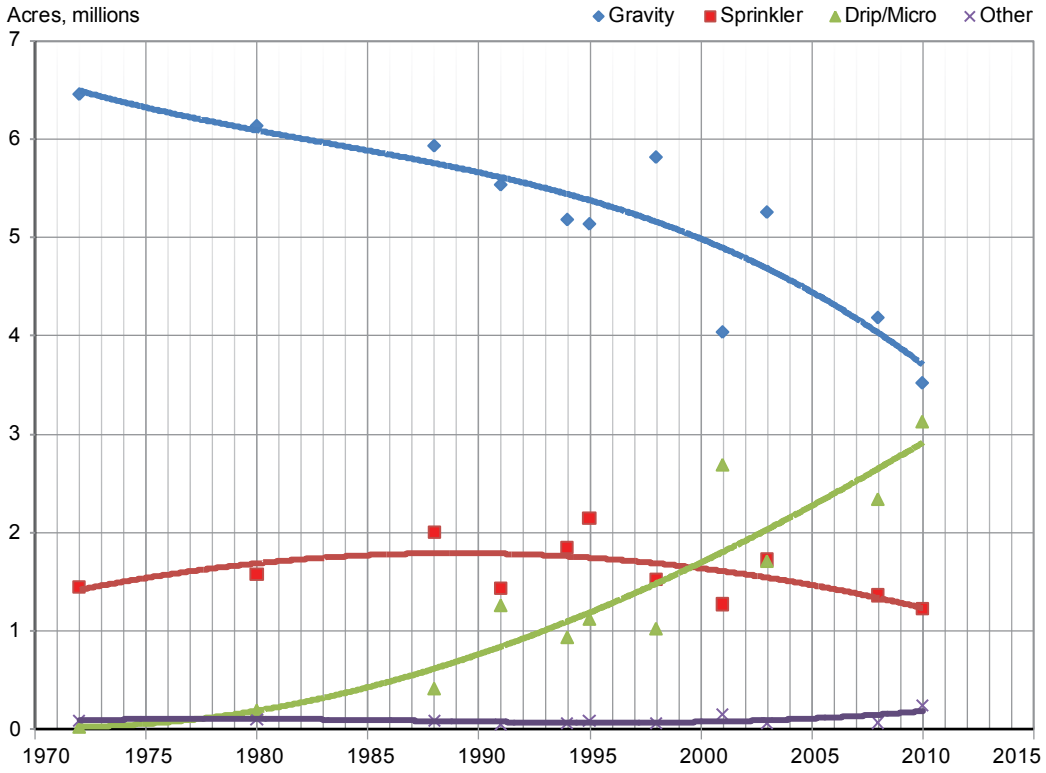


Figure 2-4 Statewide Trends in Irrigation Method Area from 1991 to 2011

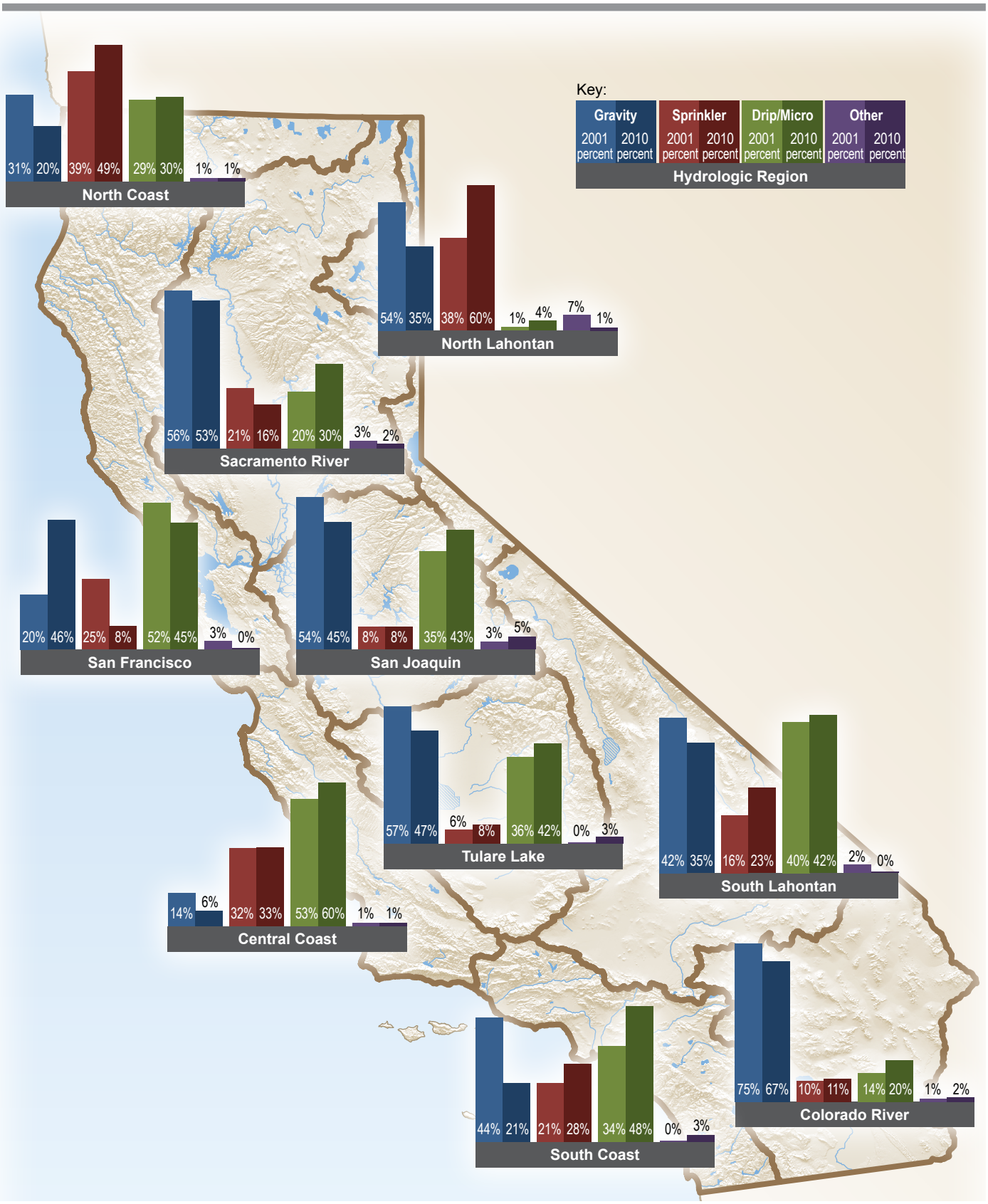


Table 2-1 Trends in Irrigation Method Area (in million acres)

Irrigation Method	1991		2001		2010		Change from 1991 to 2010	
	Area (MA)	% of Total	Area (MA)	% of Total	Area (MA)	% of Total	Percent Change in Acreage and Reduction/Increase of Area	
Gravity (furrow, flood)	5.54	67	4.04	50	3.53	43	-36%	-2.01 MA
Sprinkler	1.43	17	1.28	16	1.24	15	-13%	-0.19 MA
Drip/micro	1.26	15	2.69	33	3.12	39	+150%	+1.86 MA
Subsurface	0.05	1	0.15	2	0.24	3	+380%	+0.19 MA
Total	**8.28**	**100**	**8.16**	**100**	**8.13**	**100**	**2.01 MA reduction in gravity systems 1.86 MA increase in pressurized systems**	

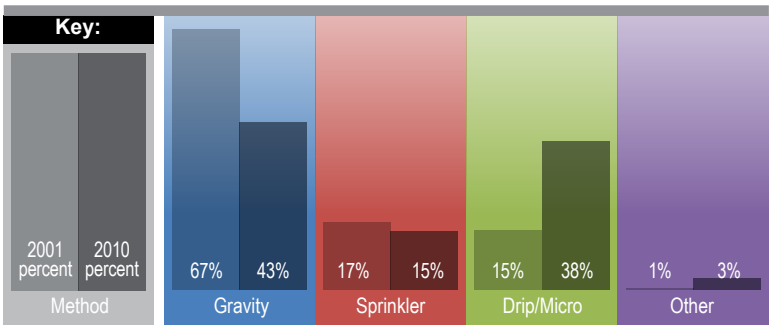
Note: MA = million acres.

geographic information system (GIS), global positioning system (GPS), and satellite crop and soil moisture sensing systems. These technologies help growers to improve overall farm water management.

Using pressurized irrigation systems, such as sprinkler, drip, and micro spray, in addition to being energy intensive often require modernization of water supplier delivery systems to provide irrigation water at the time, quantity, and duration required by the grower. An increasing trend is water suppliers 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. Because of the advancement of both water supplier and on-farm water management systems, there is potential to improve irrigation efficiencies at both the 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 (Figure 2-5). Many growers take advantage of mobile laboratory services to conduct in-field evaluation of their irrigation systems. These were once considered to be innovative technologies, but are standard practices now. 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 (Crop Life America 2012). Conversion of traditional irrigation systems to pressurized systems

Figure 2-5 Statewide Trends in Irrigation Methods



and installing advanced technologies on water supplier delivery systems require more investment in facilities as well as using 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, based on industry contacts, reports that in the six-year period, 2003 through 2008, San Joaquin Valley farmers invested more than $1.5 billion in high efficiency irrigation equipment.

Trends in irrigation methods used vary by region and such variation is mainly linked to the type of crops grown. Where more fruit trees and row crops (e.g., tomatoes) are grown, there is greater adoption of drip and micro irrigation systems.

Water Management

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

Some 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), and to the DWR 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 21, “Agricultural Land Stewardship,” in this volume) also reduce water use and contribute to sound on-farm water management.

Box 2-5 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, and 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.)

Reducing 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, which is the application of water below full crop-water requirements. It is a strategy used to stabilize crop yields in drought areas, rather than maximizing it (see Box 2-5 for more on deficit irrigation). In addition, some growers use deficit irrigation for their crops during water short periods, or for agronomic purposes, such as improving the quality of the crop. 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.

It should however be noted that there is a close correlation between yield and transpiration. In most cases, an increase in crop yield is proportionally related to an increase in transpiration. However, an increase in yield does not necessarily result into a proportionate increase in crop water consumption. Transpiration is proportional to the crop yield in terms of total plant biomass. Nonetheless, in terms of the "economic yield" (i.e., fruit, seed, and other economic parts of the biomass), there can be increase in the yield without increasing the total biomass and therefore without increasing transpiration.

Potential Benefits and Costs

Several analyses have been performed since 2000 to quantify water savings and associated costs. The following is a summary of those analyses.

The CALFED Programmatic Record of Decision (ROD) estimates of 2000 reported that efficiency improvements could result in a water savings (reduction in irrecoverable flows are also referred to as net water savings) ranging from 120,000 to 563,000 acre-feet per year (af/

yr.) by 2030, at a cost ranging from $35 to $900 per acre-foot (CALFED Bay-Delta Program 2000a). The total cost of this level of agricultural water use efficiency to 2030 is estimated to be $0.3 billion to $2.7 billion, which includes $220 million for lining the All-American Canal and Coachella Branch Canal. 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 Water Use Efficiency Program Plan (CALFED Bay-Delta Program 2000b).

The analysis used the assumption that on-farm efficiency would improve to 85 percent. The analysis assumed that the achieved 85 percent on-farm efficiency would be maintained afterward. Efficiency levels higher than 85 percent are not attainable because of technical management and hardware limitations. Further, beyond 85 percent efficiency, a loss of productivity will occur. Increased soil salinity and soil degradation will result in an unsustainable and unhealthy soil environment.

The study also estimated a 1.6 maf /yr. reduction in applied water (recoverable flows) that provide environmental and crop production benefits. The estimated water savings are from all of California's hydrological regions.

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. See Box 2-5 for discussion of regulated deficit irrigation.

Water use efficiency measures in the Colorado River Hydrologic Region are being driven by the Quantification Settlement Agreement (QSA). QSA projects will reduce irrecoverable flows by 67,700 acre-feet per year (af/yr.) at a cost of $135.65 million by lining the All-American Canal and by 26,000 af/yr. at a cost of $83.65 million by lining the Coachella Branch Canal, for a total of 93,700 af/yr. (CALFED Bay-Delta Program 2000b).

Under the QSA, agricultural water use efficiency measures adopted by the Imperial Irrigation District (IID) by 2026 will result in a reduction in delivery of Colorado River water to IID of 487,200 af/yr. inclusive of 67,700 af/yr. reductions from the All-American Canal lining. The 26,000 af/yr. Coachella Branch Canal lining is subtracted from the Coachella Valley Water District (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 thousand acre-feet per year (taf/yr.) by 2026 and for the duration of the QSA (U.S. Department of the Interior 2003). Note that the IID/Metropolitan Water District of Southern California (MWD) transfer has been fixed at 105 taf/yr. instead of 110 taf/yr. 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 af/yr. from 5.2 to 4.4 million acre-feet per year (maf/yr.) (California Department of Water Resources 2009a; U.S. Bureau of Reclamation 2003).

The 2006 CALFED Water Use Efficiency Comprehensive Evaluation estimated potential water savings for different projection levels, ranging from 34,000 to 190,000 af/yr. of irrecoverable water and 150,000 to 947,000 af/yr. of recoverable water (CALFED Bay-Delta Program 2006). These were estimates for different projection levels, based on costs ranging from $15 million to $40 million annually (Table 2-2). These costs are for implementing efficiency measures that are not locally cost-effective. It is also assumed that implementing all locally cost-effective efficiency

Table 2-2 On-Farm and Water Supplier Recoverable and Irrecoverable Flow Reductions

Estimates of 2030 On-farm and District Agricultural Water Use Efficiency Potential					
Projection Level (PL)	**Local Agency Investment Assumption**	**CALFED Grant Funding Assumption**	**Recoverable Flows (1,000 af/yr.)**	**Irrecoverable Flows (1,000 af/yr.)**	**Regulated Deficit Irrigation (1,000 af/yr.)**
PL-1	Historic Rate	Prop. 50 only	150	34	142
PL-2	Locally Cost-Effective	Prop. 50 only	No change in locally cost-effective rate-results, same as PL-1		
PL-3	Historic Rate	Prop. 50 + $15 million/year	565	103	142
PL-4	Locally Cost-Effective	Prop. 50 + $15 million/year	No change in locally cost-effective rate-results, same as PL-1		
PL-5	Locally Cost-Effective	Prop. 50 + $40 million/year (2005-14) $10 million/year (2005-30)	947	190	142
PL-50	Locally Cost-Effective	Prop. 50 $150 million/year (2006-2030)	2006	620	142
PL-00	Locally Cost-Effective	Prop. 50 $500 million/year (2006-2030)	2,930	888	142

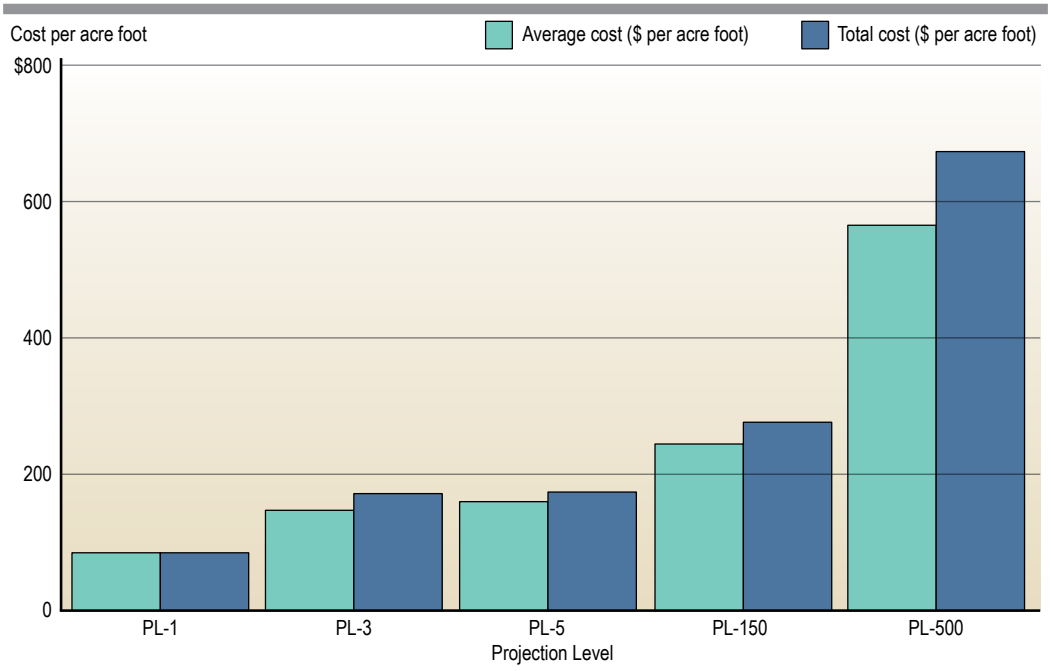
Funding assumptions are based on implementation costs of not locally cost-effective efficiency measures and are not divided between local and public funding.

Source: Water Use Efficiency Comprehensive Evaluation. CALFED Bay-Delta Program Water Use Efficiency Element Final Report (CALFED, 2006). The CALFED report is an updated analysis to the CALFED Bay-Delta Program Water Use Efficiency Element.

Note: af/yr. = acre-feet/year

measures are, and will continue to be, paid by local agencies and growers. The analysis also provided the maximum water savings achievable at the field and district levels if cost is not a barrier. Water savings at this projection level (PL) is called technical potential (Projection Level 6 or PL-6). Technical potential was defined as the savings resulting from 100 percent adoption of all agricultural water use efficiency actions/measures statewide, and assumed that all technically demonstrated practices would be implemented regardless of cost. The technical potential, or PL-6 water savings, at an estimated cost of $1.6 billion, are 1.8 maf/yr. irrecoverable water savings and 4.3 maf/yr. per year recoverable water savings. PL-6 was determined to be unrealistic both with respect to State's ability to provide such large funds and level of water savings. PL-6 represents a perfect irrigation system and management performance that is not attainable in production agriculture. The analysis also indicates a potential for additional water savings of 142,000 af annually from regulated deficit irrigation. Figure 2-6 presents average and incremental costs per acre-foot of irrecoverable flows for all projection levels in this study. The study 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

Figure 2-6 Average and Incremental Cost per AF of Irrecoverable Loss Reduction



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 improvements were analyzed based on natural replacement from lower to higher performing systems over time (as systems age out and are replaced with new technology) as well as various funding levels. Water supplier improvements were based on implementation of efficient water management practices and various funding levels. The potential savings estimated in the study are based on a set of specific assumptions about the distribution and effective use of investments in agricultural water use efficiency (CALFED 2006). The cost information in Table 2-2 represents the investment in water use efficiency actions beyond the estimated locally cost-effective actions.

A July 2009 report from the Pacific Institute, *Sustaining California Agriculture in an Uncertain Future*, is another analysis to quantify agricultural water savings (Cooley et al. 2009). 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 — wet, average, and dry year conditions. The total potential water savings range between 4.5, 5.5, and 5.9 maf/yr. 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.

There is no doubt that agricultural water use efficiency can still be improved by continuing current trends such as improving irrigation efficiency, adopting drip and micro irrigation, adopting reduced deficit irrigation, selecting water efficient crops, etc. However, the potential for water savings from agricultural water use efficiency has been the subject of a broad debate.

At the high end, some reports mention potential savings to be as much as five million acre-feet of water per year by 2030 (Gleick et al. 2005). Others caution that any approach to estimate the potential of developing new water supplies through agricultural water conservation must acknowledge the difference between recoverable and irrecoverable flows. More important is that potential water savings should be tied to different levels of investment (Canessa et al. 2011). A report from the Center for Irrigation Technology at California State University, Fresno concludes that the potential of large volumes of "new water" from agricultural water conservation does not exist unless large swaths of agricultural land are taken out of production (land retirement), which technically is not water use efficiency (Canessa et al. 2011). See the land retirement section in Chapter 32, "Other Strategies," in this volume. Also among the Center for Irrigation Technology report findings are:

1. The estimated potential of new water from agricultural water use efficiency is 1.3 percent of the current amount used by the farmers or approximately 330,000 acre-feet per year (at funding level PL-5 identified in Update 2009). That represents about 0.5 percent of California's total water use.

2. Changes in irrigation practices, such as switching from flood irrigation to drip, have the effects of rerouting flows within the region (or basin), but generally do not create new water outside of the basin.

3. On-farm water conservation efforts can affect downstream water distribution patterns with potential impacts on plants and animals, recreation, as well as human and industrial consumptive uses. Effects can be positive or negative and also inconsistent (e.g., on-farm conservation could reduce a city's water supply but decrease non-point source pollution (Canessa et al. 2011). (See Chapter 18, "Pollution Prevention," in this volume.)

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 baseline of water supplier improvements was developed for every hydrologic region by the former CALFED Bay-Delta Program based on water availability and knowledge of local delivery capabilities and practices. In addition, it 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.

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.

On-Farm Water Use Efficiency

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 unpressurized 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. Recoverable flows encompass surface runoff and deep percolation to usable water bodies. The recoverable flow results are based on instream flow needs for Bay-Delta tributaries. It is important to note 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. (See Box 2-6, Interrelation between On-farm and Regional Efficiencies and Role of Water Reuse.)

A primary environmental benefit of water use efficiency actions is the improvement in aquatic habitat through changes to instream flow and timing. Additional benefits may include water quality improvements by reducing water temperature, subsurface drainage flows, and reducing contaminant loads. Growers may reduce pumping costs and may provide and/or receive water quality benefits by complying with pollutant reduction rules under the State's total maximum daily load (TMDL) requirements. 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 drain water contaminants, such as selenium, are isolated and properly disposed.

Major Implementation Issues

Funding

Beginning in 2000, DWR implemented several cycles of grant programs for water use efficiency improvements. The funds have been awarded 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 for the implementing agency. The grant cycles are summarized in Table 2-3. Grant funding has been provided statewide for a variety of projects including:

- Urban and agricultural water use efficiency implementation projects that are not locally cost-effective and that provide water savings or contribute to instream flows that are beneficial to the Bay-Delta or the rest of the state. Consideration is also given to projects that address water quality and energy efficiency.
- Urban and agricultural water use efficiency non-implementation projects including:
  - Planning.
  - Research and development projects.

Table 2-3 Projects Funded through Water Use Efficiency Grant Cycles Since 2001

	Urban Grants		Agricultural Grants		Total Grants	
GRANT SOURCE	FUNDING (MILLION)	NUMBER OF PROJECTS	FUNDING (MILLION)	NUMBER OF PROJECTS	FUNDING (MILLION)	TOTAL # OF PROJECTS
2013 Prop 50	-	-	$15	39	$15	39
2008 Prop 50	$17.2	53	-	-	$17.20	53
2007 Prop 50	$18.2	35	$9.9	22	$28.10	57
2005 Prop 50	$16.9	46	$11.7	28	$28.60	74
2003 Prop 13	$18.0	25	-	-	$18.00	25
2002 Prop 13	$8.5	21	$0.7	8	$9.20	29
2001 Prop 13	$0.7	7	$0.5	5	$1.20	12
2001 SB 23	$5.9	30	$5.9	23	$11.80	53
Total	**$85.4**	**217**	**$47.1**	**86**	**$132.50**	**303**

- Feasibility studies.
- Pilot studies or demonstration projects.
- Training, education, or public outreach programs.
- Technical assistance programs related to water use efficiency.

Cost-effectiveness criteria do not apply to these projects, but their outcome should be transferable to other areas of the state.

Funds dedicated to water use efficiency have fallen below estimates of the 2000 CALFED ROD that called for an investment of $1.5 to $2 billion from 2000 to 2007. The CALFED ROD stated that state and federal governments would fund approximately 50 percent (25 percent each), and local agencies would pay for the remaining 50 percent of CALFED water use efficiency activities. Table 2-3 shows the total funding for urban and agricultural water use efficiency projects (implementation as well as non-implementation) has been $132.5 million from 2000 through 2013.

Although small and disadvantaged communities must have grants for sorely needed water system improvements, they may not be able to apply because they have limited resources and matching funds. In addition, such water suppliers rarely have the technical and financial abilities to develop plans or implement expensive water management practices. During previous Proposition 50 water use efficiency grant cycles, DWR has made significant efforts to provide technical and financial assistance to disadvantaged communities. SB X7-7 requires DWR to give consideration to disadvantaged communities when allocating funds.

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.

Box 2-6 Interrelation 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 evaporating from soil or flowing to salt sinks, such as saline surface or groundwater, or to the 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 the water in the agricultural setting is used and reused many times over, including re-use of water in wetlands. It is because irrigation water is reused that on-farm efficiency improvements will not result in regional water savings. Regional efficiencies, with few exceptions such as drainage problem areas and salt sink areas, are 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.

Implementation

Implementing agricultural water use efficiency depends on many interrelated factors. Farmers strive to maximize 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, 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. Implementation of efficiency measures requires consideration of crops grown, groundwater and/or surface water availability, and water quality within each geographic area. Opportunities exist to implement efficiency measures beyond basic 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 include, to the extent possible, multi-purpose and multi-benefit projects.

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. (See Box 2-5 for a discussion of regulated deficit irrigation.)

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 taken away, hence losing their rights to use the conserved water. This belief may impede implementing water use efficiency strategies. It should

be noted that the water rights of agencies implementing efficiency measures have been protected. One example is the conservation efforts of IID, funded by MWD, SDWA, and others, where water was transferred to urban uses while IID's water rights were protected.

Energy and Water Relationship

The relationship between water use efficiency and energy use/carbon footprint is complex and needs to be thoroughly studied and understood. Improved agricultural water use efficiency may or may not help to reduce energy use and thus reduce greenhouse gases (GHGs). This is because of the complex relationship between GHG emissions, the use of energy (use of natural gas and the use of fossil fuel), and efficient use of water. It appears that decreased use of one resource, through implementation of efficiency measures, increases the use of another resource, which may neutralize or greatly impact net outcome, and often has more overall adverse effects than intended or desired. There have not been enough studies and research conducted to quantify the relationship between agricultural water use efficiency and energy use.

By considering the embedded energy of irrigation water, which is the energy required to deliver water to the field, California State University at Fresno's Center for Irrigation Technology showed in its 2011 report that water use efficiency may reduce or increase energy use. By reducing irrigation water through water use efficiency, generally the embedded energy would always be saved. However, the water use efficiency method employed might require a change in the irrigation system (e.g., changing the irrigation system from flood to drip). In such a case, even though the embedded energy is reduced, the energy required to apply the water to the field is increased. As a result, whether water use efficiency results in a net decrease or increase in energy use depends on the amount of water saved, the level of embedded energy, and the additional energy required to pressurize the irrigation system.

Climate Change

One of the most critical impacts on California agriculture may be the projected reduction in the Sierra Nevada snowpack, which is California's largest surface "reservoir." Snowmelt currently provides an annual average of 15 maf of water, which is slowly released between April and July each year. Much of the state's water infrastructure was designed to capture the slow spring runoff and deliver it during the peak of the agricultural water use season. Based on historical data and modeling, DWR projects that the Sierra snowpack will experience a 25-40 percent reduction of its historical average by 2050. Climate change is also anticipated to bring warmer storms that result in less snowfall at lower elevations, which reduces the total snowpack. The snowpack will melt earlier in the season due to warmer temperatures and there will be less late-season runoff. Warmer temperatures and increased atmospheric concentrations of carbon dioxide (CO_2) also increase ET and crop water demand. All of these factors will further stress California's agricultural community (California Department of Water Resources 2008, 2009b, 2010).

Mitigation

On-farm and water use efficiency improvements often require additional energy. Converting furrow irrigation to drip or sprinkler would require significant energy, even though growers and/or water suppliers may pump less water, which may reduce energy use. Therefore, the

overall result of such efficiency practices may be a net increase of energy use. Water supplier infrastructure improvements often affect upstream-downstream water use. Also, increasing the use of pressurized irrigation systems by growers requires 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 its useful life. Consequently, significant additional energy is required for manufacturing pipelines, pumps, filters and filtration systems, chemicals, and the replacement and disposal of the hardware. Likewise, pressurized irrigation systems will need energy to produce the required pressure in the pipelines for irrigation. Such additional energy will significantly increase GHG emissions, which contribute to climate change. Within the agricultural setting, the net impact of reduced water use and increased water use efficiency on the energy use and consequently on net carbon footprint, water footprint, and GHG emissions calls for study and quantification of such impacts.

Adaptation

Agricultural water use efficiency is an adaptive strategy to climate change. Using water in a way that is most effective to the crop while minimizing losses helps the grower to be resilient and flexible. Climate change is a major challenge to agriculture's sustainability. The water use efficiency strategies discussed above are part of California's adaptive capacity, but growers must find a way to store more water in preparation for having access to less water during peak growing months in addition to using that water efficiently. Cover cropping and organic material build-up in soil are other methods of increasing soil water retention, which lessens the amount of irrigation water needed.

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 a changing climate. Climate change is expected to impact water use since rising temperatures will result in higher ET and higher crop water use requirements.

Education and Training

Improving agricultural water use efficiency depends on 1) disseminating information on the use, costs, benefits, and impacts of technologies, 2) providing technical assistance and training on the site specific nature of implementing technology, and 3) providing incentives for implementation. Experience shows that water suppliers and growers respond strongly to financial incentives. In addition, while the CWC 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 both the potential benefits and the risks of efficiency improvements, including the risks to soil sustainability from a salinity standpoint, or that energy use may increase. On-site technical assistance can assist growers in successfully implementing new technologies more efficiently and in site-specific ways.

With limited water resources and recurring droughts, California farmers, irrigation specialists, water resources planners, and water managers use a multitude of information sources for informed decision- making and to stay current on the latest issues and advances in irrigation technology and water management practices. Such sources of information include, but are not limited to: State and federal agencies and research stations; U.S. Department of Agriculture, Natural Resources Conservation Service; resource conservation districts; UC Cooperative Extensions and Agricultural Experiment Stations; Cal Poly Irrigation Training and Research Center; California State University, Fresno, Center for Irrigation Technology; California Irrigation Institute; California Irrigation Districts Association; independent crop advisors; and many growers associations and irrigation equipment vendors.

Dry-Year Considerations

In dry years, California's water supply is inadequate to meet the current level of use, and agriculture often must deal 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 practices or even fallow land. While agricultural water suppliers deal in a variety of ways with water shortages and droughts, there is a need for an agricultural drought guidebook.

Overall, water scarcity impacts California growers and as climate change continues to reduce the average annual snowpack, it is likely that droughts in California may increase in severity and frequency in years to come. In the 1970s and early 1990s, DWR partnered with the University of California Agriculture and Natural Resources (UCANR) to develop a series of drought management fact sheets. There is a need to update these facts sheets and make them more readily available. DWR, in cooperation with UCANR, is embarking on a project to revisit and update existing drought tips and fact sheets on drought and agriculture in California and potentially develop new ones. As more and more people get their information from the web, it is important to provide the updated information using a variety of digital formats that will achieve broader outreach such as a drought information clearinghouse Web site.

Recommendations

The following recommendations can help facilitate greater agricultural water use efficiency.

Implementation

1. 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. The State should verify and clarify in its programs, especially loans and grant programs, that efforts to conserve water do not alter water rights. SB X7-7 legislation declares that it "does not require a reduction in the total water used in the agricultural or urban sectors, because other factors, including, but not limited to, changes in agricultural economics or population growth may have greater effects on water use. This part does not limit the economic productivity of California's agricultural, commercial, or industrial sectors" (CWC Section 10608.8(3)(c)).

2. DWR, in cooperation with academic institutions, resource conservation districts, and independent crop advisors should provide technical assistance to water suppliers and farmers to evaluate their agricultural water use efficiency by computing the efficiency quantification methods outlined in the DWR 2012 report to the Legislature, A Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use.

3. DWR should continue developing, in consultation with the State Water Resources Control Board, the California Department of Public Health, and the Public Utilities Commission, a single standardized water use reporting form to meet the water use information needs of each agency.

4. DWR should provide technical assistance to water suppliers to help them implement the Agricultural Water Measurement Regulation and report aggregate farm-gate deliveries to comply with the regulation.

Data Measurement and Evaluation

5. DWR should create a statewide system of water use monitoring data available to all users.

6. The State should expand water efficiency information, evaluation programs, and on-site technical assistance provided through agricultural extension services, resource conservation districts, independent crop advisors, and other agricultural outreach efforts.

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

8. 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. The State should also 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 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.

9. The State should incorporate into its definitions of "efficiency measures" and "cost-effectiveness" ownership and operating costs, including labor, energy, and cost of maintenance.

10. 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.

11. DWR, in cooperation with the Department of Food and Agriculture and irrigation districts, should establish an on-farm irrigation system evaluation program, such as mobile labs, statewide. The irrigation system evaluation program provides valuable assistance to growers to improve the performance of their irrigation systems further.

12. Using data and information from on-farm efficiency improvements collected by mobile labs, DWR should quantify changes in irrigation system distribution uniformity improvements. Protocols for confidentiality should be followed to ensure that information identifying

individual fields, owners, or operators is not improperly disclosed in order to assure farmers and encourage voluntary participation. In addition to quantifying on-farm and regional efficiency, collected data — stripped of any personal or business information — can also be used for improving local, regional, and statewide water management planning.

Education and Training

13. Expand CIMIS (including remote sensing technology, satellite imagery, etc.), mobile laboratory services, and other training and education programs to improve irrigation distribution uniformity, irrigation scheduling, and on-farm irrigation efficiency. These program expansions should also be used for improvements in pumping system efficiencies, remote control technologies and telemetry, canal automations, flexible water delivery systems, and irrigation system design.

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

15. DWR, with the participation of agricultural and water industries and environmental interests, should develop community educational and motivational strategies for conservation activities to foster water use efficiency.

16. 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.

17. The State should foster a closer cooperative relationship among growers, water suppliers, irrigation professionals, technical assistance providers, and manufacturers who play an important role in research, development, manufacturing, distribution, and dissemination of new and innovative irrigation technologies and management practices.

18. The State should initiate collaboration with county governments to offer tax credits for installation of more efficient irrigation systems.

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

Dry-Year Considerations

20. DWR, the Department of Food and Agriculture and stakeholders should compile measures currently used 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.

21. 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.

22. Drought water management should be fully incorporated in agricultural water management plans.

Department of Water Resources' Near-Term Core Programs

23. Continue developing a single standardized water use reporting form, in consultation with the State Water Resources Control Board, the Department of Food and Agriculture, Department of Public Health, and Public Utility Commission. DWR will involve agricultural water suppliers and stakeholders in the process through the existing Urban Stakeholders Committee and Agricultural Stakeholders Committee. Agricultural water suppliers will use the form to report water use data and information, at a minimum to show compliance with the implementation of EWMPs as required in SB X7-7.

24. Continue developing an on-line submittal portal for water suppliers to use in reporting water use data, EWMPs, and AWMPs.

25. Prepare and submit reports on the results of efficiency improvements in irrigation systems to the Legislature.

26. Make all submitted agricultural water management plans available for public inspection on the DWR Web site.

27. Prepare and submit to the Legislature reports summarizing the status of the Agricultural Water Management Plans and adoption by the agricultural water suppliers. These reports shall be prepared on or before December 2013 and in subsequent years ending with six and one (e.g., 2016, 2021).

References

References Cited

Agricultural Water Management Council AB 3616 Advisory Committee. 1999. Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California. Sacramento (CA): California Department of Water Resources. 87 pp. Viewed online at: http://www.agwatercouncil.org/images/stories/pdfs/awmcmou.pdf.

Burt CM, Mutziger A, Howes D, Solomon K. 2002. *Evaporation from Irrigated Agricultural Land in California.* San Luis Obispo (CA): Irrigation Training and Research Center, California Polytechnic State University. 478 pp.

CALFED Bay-Delta Program. 2000a. Programmatic Record of Decision (ROD). Sacramento (CA): CALFED Bay-Delta Program. 846 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/ROD.pdf.

———. 2000b. "Water use efficiency program plan. Programmatic EIR/EIS technical appendix." Sacramento (CA): California Bay-Delta Program. 29 pp. [Web site.] Viewed online at: http://calwater.ca.gov/calfed/library/Archive_EIS.html.

———. 2006. *Water Use Efficiency Comprehensive Evaluation. CALFED Bay-Delta Program Water Use Efficiency Element. Final Report*. Sacramento (CA): California Bay-Delta Program. 181 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/library/WUE/2006_WUE_Public_Final.pdf.

California Department of Food and Agriculture. 2012. *California Agricultural Statistics Review.* 2011-2012. Sacramento (CA): California Department of Food and Agriculture. 15 pp. Viewed online at: http://www.cdfa.ca.gov/statistics/pdfs/AgStatOverview2011-12.pdf.

California Department of Water Resources. 2008. *Managing an Uncertain Future*. Sacramento (CA): California Department of Water Resources. 34 pp. Viewed online at: http://www.water.ca.gov/climatechange/docs/ClimateChangeWhitePaper.pdf.

———. 2009a. Colorado River Hydrologic Region. In: *California Water Plan Update 2009*. Chapter 11. Volume 3. Sacramento (CA): California Department of Water Resources. 58 pp. [Book.] Viewed online at: http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v3_coloradoriver_cwp2009.pdf.

———. 2009b. "Climate Change." Sacramento (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.water.ca.gov/climatechange/. Accessed: Dec., 2009.

———. 2012a "Agricultural Water Use." Sacramento (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.water.ca.gov/wateruseefficiency/agricultural/.

———. 2012b. *A Proposed Methodology for Quantifying the Efficiency of Agricultural Water Use. A Report to the Legislature Pursuant to Section 10608.64 of the California Water Code*. Sacramento (CA): California Department of Water Resources. 105 pp. Viewed online at: http://www.water.ca.gov/wateruseefficiency/sb7/docs/AgWaterUseReport-FINAL.pdf.

California Roundtable on Water and Food Supply. 2011. *Agricultural Water Stewardship: Recommendations to Optimize Outcomes for Specialty Crop Growers and the Public in California*. Sebastopol (CA): Ag Innovations Network. 12 pp. Viewed online at: http://aginnovations.org/images/uploads/CRWFS_Water_Stewardship_Recs_electronic.pdf.

Canessa P, Green S, Zoldoske D. 2011. *Agricultural Water Use in California: A 2011 Update*. Fresno (CA): Center for Irrigation Technology California State University, Fresno. 80 pp. Viewed online at: http://www.californiawater.org/docs/CIT_AWU_Report_v2.pdf.

Center for Irrigation Technology. 2009. "Center for Irrigation Technology." Fresno (CA): California State University, Fresno. [Web site.] Viewed online at: http://www.fresnostate.edu/jcast/cit/index.html. Accessed: Dec., 2009.

Christian-Smith J, Allen L, Cohen MJ, et al. 2011) *California Farm Water Success Stories*. Oakland (CA): Pacific Institute. 74 pp. Viewed online at: http://www.pacinst.org/reports/success_stories/.

Cooley H, Christian-Smith J, Gleick P. 2009. *Sustaining California Agriculture in an Uncertain Future*. Oakland (CA): Pacific Institute. 81 pp. Viewed online at: http://www.pacinst.org/reports/california_agriculture/final.pdf.

Crop Life America. 2012. *Annual Report*. Washington (DC): Crop Life America. 24 pp. Viewed online at: http://www.croplifeamerica.org/sites/default/files/CLA_Annual%20Report_FINAL_9%2012%2012.pdf.

Gleick P, Cooley H, Groves D. 2005. *California Water 2030: An Efficient Future*. Oakland (CA): Pacific Institute. 48 pp. Viewed online at: http://www.pacinst.org/reports/california_water_2030/ca_water_2030.pdf.

Independent Panel on Appropriate Measurement of Agricultural Water Use. 2003. *Final Report on the Definition of Appropriate Agricultural Water Use Measurement*. Sacramento (CA): California Bay-Delta Authority. 131 pp. Viewed online at: http://www.calwater.ca.gov/content/Documents/library/WUE/FinalReport_Sept03.pdf.

Northern California Water Association. 2011. *Efficient Water Management for Regional Sustainability in the Sacramento Valley*. Sacramento (CA): Prepared by CH2M Hill, Davids Engineering, and MBK Engineers for the Northern California Water Association. 50 pp. Viewed online at: http://www.norcalwater.org/wp-content/uploads/2012/01/Technicalreport-jul2011.pdf.

Orang M, Matyac S, Snyder R. 2008. "Survey of irrigation methods in California in 2001." Journal of Irrigation and Drainage Engineering. 134(1):96-100. [Technical note.]

San Diego County Water Authority. 2003. Quantification Settlement for the Colorado River. San Diego (CA): San Diego County Water Authority. 2 pp. Viewed online at: http://www.sdcwa.org/sites/default/files/files/publications/qsa-fs.pdf.

U.S. Bureau of Reclamation. 2003. Colorado River Water Delivery Agreement: Federal Quantification Settlement Agreement for purposes of Section 5(B) of Interim Surplus Guidelines. Prepared for Secretary of the Interior, Imperial Irrigation District, Coachella Valley Water District, Metropolitan Water District of Southern California, and San Diego County Water Authority. Washington (DC): U.S. Bureau of Reclamation. 14 pp. Viewed online at: http://www.usbr.gov/lc/region/g4000/QSA/crwda.pdf.

U.S. Senate Committee on Agriculture, Nutrition, and Forestry. 2012. "The Farms Bill is a Job Bill. Agriculture Reform, Food, and Jobs Act of 2012." Washington (DC): U.S. Senate Committee on Agriculture, Nutrition, and Forestry, U.S. Senator Debbie Stabenow, Chairwoman. [Executive summary.] Viewed online at: http://www.stabenow.senate.gov/files/documents/fb-jobs.pdf.

Wilson CM. 2011. *The Reasonable Use Doctrine and Agricultural Water Use Efficiency*. Sacramento (CA): 17 pp. Prepared for the State Water Resources Control Board and the Delta Stewardship Council. Viewed online at: http://www.waterboards.ca.gov/board_info/agendas/2011/jan/011911_12_reasonableusedoctrine_v010611.pdf.

Additional References

Agricultural Water Management Council. 2009. "Agricultural Water Management Council." Fresno (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.agwatercouncil.org/. Accessed: Dec., 2009.

California Department of Water Resources. 2009c "Grants and Loans." Sacramento (CA): California Department of Water Resources. [Web site.] Viewed online at: http://www.water.ca.gov/nav/nav.cfm?loc=t&id=103. Accessed: Dec., 2009.

——. 2009d. "California Irrigation Management Information System (CIMIS)" Sacramento (CA): California Department of Water Resources, Office of Water Use Efficiency. [Web site.] Viewed online at: http://wwwcimis.water.ca.gov/cimis/welcome.jsp. Accessed: Dec., 2009.

California Farm Water Coalition. 2009. "California Farm Water Coalition." Sacramento (CA): [Web site.] Viewed online at: http://www.cfwc.com/. Accessed: Dec., 2009.

California Polytechnic State University. 2009. "Irrigation Training and Research Center." San Luis Obispo (CA): California Polytechnic State University. [Web site.] Viewed online at: http://www.itrc.org. Accessed: Dec. 2009.

Imperial Irrigation District. 2009. "Agreements with the Federal Government and Southern California Agencies." Imperial (CA): Imperial Irrigation District. [Web site.] Viewed online at: http://www.iid.com/index.aspx?page=208. Accessed: Dec., 2009.