Discussion Paper 1: Initial Draft Methodology for Quantifying the Efficiency of Agricultural Water Use (Project A1)

[*Note: This paper is still a work in progress and represents DWR staff's initial draft methodology for quantifying the efficiency of agricultural water use. The draft methodology is based upon preliminary understanding of provisions in the Water Conservation Act of 2009, referred to below as SBx7-7, and is not considered to be DWR's official position. DWR invites comment and input on the draft methodology and identified questions as presented in this paper. Comments should be submitted to DWR staff at agwue@water.ca.gov.*]

SBx7-7, enacted in November of 2009, includes provisions on water conservation, measurement, and reporting activities for agricultural water suppliers. DWR is coordinating with the Agricultural Water Management Council, academic experts and other stakeholders to develop a methodology for quantifying the efficiency of agricultural water use.

1.0 Provisions of SBx7-7 Related to Quantifying Agricultural Water Use Efficiency

Paragraph 10608.64 of SBx7-7 states:

> *The department, in consultation with the Agricultural Water Management Council, academic experts, and other stakeholders, shall develop a methodology for quantifying the efficiency of agricultural water use. Alternatives to be assessed shall include, but not be limited to, determination of efficiency levels based on crop type or irrigation system distribution uniformity. On or before December 31, 2011, the department shall report to the Legislature on a proposed methodology and a plan for implementation. The plan shall include the estimated implementation costs and the types of data needed to support the methodology. Nothing in this section authorizes the department to implement a methodology established pursuant to this section.*

2.0 DWR Staff's Understanding and Draft Methodology

DWR staff defines the "quantification of the efficiency of agricultural water use" as a concept that can be applied at different scales with different indicators, to reflect a degree to which water diverted from surface and/or groundwater systems serves a desired effect. Ultimately, the desired effect associated with agricultural water use is to produce agricultural goods.

However, the concept of quantifying the efficiency of agricultural water use does not universally correlate to the concept of "water use efficiency," which is often considered to be an indicator of the ratio of (1) water consumed by a crop for evapotranspiration (ET), to (2) water applied to a field to serve the crop's ET demand. Rather, DWR staff view the concept of the efficiency of agricultural water use to incorporate a range of information and indicators, requiring data collection and calculations for different locations, scales, and time periods in the water delivery system.

From this definition, the methodology developed and reported to the Legislature by December 31, 2011 will address efficiency at different spatial scales of agricultural water use. Appropriate scales, as defined below, should include: (1) field scale, (2) agricultural water supplier scale, and (3) regional scale. These scales are not simply different levels of aggregation for reporting. That is, a supplier-level quantification of the efficiency of agricultural water use is not simply a weighted average of the field scale determinations of the efficiency of agricultural water use. Rather, the supplier’s scale would take into account the flow of water to, from, and between fields and farms (i.e., return flow, reuse, and conveyance loss) and potentially water needed for environmental objectives or other non-traditional beneficiaries that drive the operation and management of agricultural water.

SBx7-7 does not authorize implementation of a methodology, nor does it define the purposes of the quantification. In general, quantified indicators of the efficiency of agricultural water use can serve a number of purposes: they can help maintain or improve the management of water for an array of defined purposes; improve the understanding of the efficiency of agricultural water use; and guide projects, programs, and policies at local, regional, and state levels. Methodologies for quantifying the efficiency of agricultural water use also provide a foundation to support other goals, including: recognizing the value of historic investments in water systems and management, understanding the benefits and limitations of current systems and management practices, and evaluating the benefits of change to current systems and management practices.

A critical element of developing the methodology at each scale is identifying the data needed to quantify efficiency. For example, the legislation states that the methodology must include consideration of crop type and irrigation system distribution uniformity. For determining the field scale efficiency of agricultural water use, seasonal irrigation application rates and crop-specific evapotranspiration would be required. For determining efficiency at the scale of a water supplier or a region, data would at least include stream or canal diversion quantities and return flow measurements.

2.1 Suggested Spatial Scales

DWR staff suggests methodologies should be developed independently for each of the following spatial scales:

- Field Scale: This scale allows an assessment of a variety of attributes associated with irrigation system(s) and management within a field, allowing an operator to evaluate the performance of an individual irrigation system for a particular crop at a particular point in time. This assessment will, among other attributes, allow an operator to measure the effectiveness of the existing irrigation system (both physical and management elements) to supply water throughout the field – typically referred to as *distribution uniformity* – as well assess the relationship between the quantity of water applied and the primary goal of crop production.

- Agricultural Water Supplier Scale[1]: The goal of an agricultural water supplier is to use infrastructure and management (operations, pricing, etc.) to most reliably delivery available water supplies to the field scale irrigation systems. This function may be provided on a real-time basis (e.g. deliver water directly from a point of diversion to the fields) or on a delayed basis (e.g. deliver water to storage – near-term or long-term and either at the surface or in an aquifer) for later retrieval and delivery to the field (either by the supplier or by the field systems). Collecting data at this scale allows an evaluation to indicate the relations between water brought into the boundaries of an agricultural water supplier and the effectiveness of the supplier to meet its primary goal.
- Regional Scale: For purposes of defining a methodology at this scale, DWR staff has contemplated the potential use(s) of a regional methodology. One prominent use would be the California Water Plan Update. In the Update, DWR historically gathers and assesses information at a regional boundary called the Detailed Analysis Unit (DAU). For purposes of discussion, DWR staff is suggesting the DAU regional scale be used to develop a methodology at this scale.

Do the above spatial scales provide for an appropriate range of data collection and analysis to quantify the efficiency of agricultural water use?

How should the “efficiency of agricultural water use” be defined if different from the concept as described by DWR above?

Should regional scales be aligned with Integrated Regional Water Management Planning regions to allow for further integration of data and to facilitate IRWMP planning and implementation activities?

2.2 Options for a “Methodology”

As defined by Merriam-Webster Dictionary (on-line version), the term “methodology” is defined as:

1. *a body of methods, rules, and postulates employed by a discipline: a particular procedure or set of procedures*
2. *the analysis of the principles or procedures of inquiry in a particular field*

In this context, DWR is considering three options that could form the basis for the methodology developed to “quantify the efficiency of agricultural water use” under each proposed spatial scale. As described below, Option 2 and Option 3 essentially build-upon Option 1, where Option 1 defines the basic elements of any methodology. Irrespective of spatial scale, these options include:

Option 1 *- Defined data and collection procedures* – This option would focus on establishing a set of procedures that define how data would be collected at each scale – but not necessarily what data is collected or how the data can be used as an indicator of the efficiency of

[1] In this context, Agricultural Water Supplier is defined in Section 10608.12 and means “a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding recycled water.”

agricultural water use. These procedures would define the protocols for sound and timely data collection as appropriate for each spatial scale. This option would not specify what data to collect – but instead capture the broad range of data used to calculate an array of indicators. The choice of indicators would be deferred instead to professional entities and institutions to use the defined data procedures as appropriate.

Option 2 – *Collect data and apply to a single defined indicator* – This option would define the procedures for an identified indicator – limiting those procedures to only the data necessary to calculate the suggested indicator that would be used to display the efficiency of agricultural water use for the particular scale. The resulting value from the input of data into the defined indicator would be the defacto representation of the efficiency of agricultural water use at the particular spatial scale.

Option 3 – *Collect data and apply to multiple defined indicators* – In contrast to Option 2, this option would present a suite of indicators that each in their own way contribute to quantifying the efficiency of agricultural water use. Each indicator would be represented by a formula (or set of formulas), each with a defined set of input data, calculation methods, data collection and quality control standards, and temporal scales to guide data collection and use of results.

Each spatial scale may best benefit from defining the quantification method using a *different* option than another scale. After contemplating these options for each spatial scale, DWR staff is proposing the following use of the options at each spatial scale.

Are additional options available that would provide a usable methodology?

2.3 Field Scale Proposal

At this spatial scale, DWR staff is suggesting Option 3 be used to define the methodology. This option is being chosen for several reasons:

- The legislation states that alternatives to be assessed shall include determinations of efficiency levels based on crop type or irrigation system distribution uniformity.
- At the field scale, there is no single globally applicable indicator (and associated formula(s)) to represent the efficiency of agricultural water use, since variations exist in cultural practices, environmental stewardship objectives, and regional water management practices. For instance, if a simple formula that divides the ET of applied water by the amount of applied water were to be compared for the same crop but with one in a region with frost issues and another without, then one would, by definition, seem "less efficient" than the other (since frost protection usually does not contribute to crop ET).
- Multiple indicators can be used to describe the efficiency of water use by agriculture at the field scale, with the combination of indicators providing more value than any one indicator.

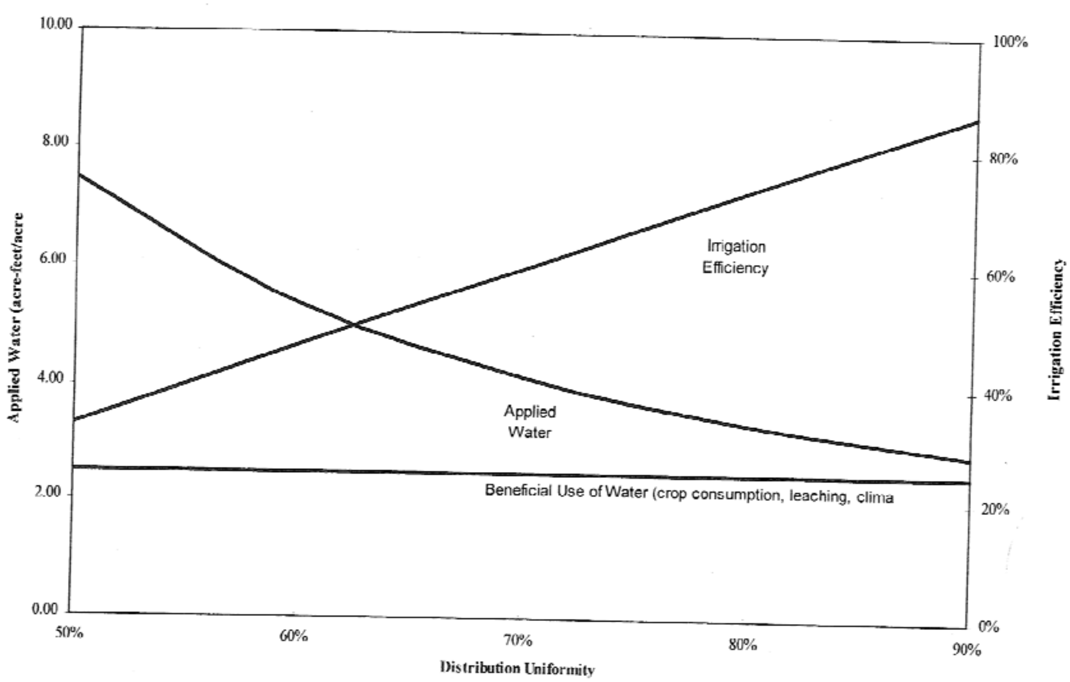
2.3.1 Field Scale Indicators

DWR staff is recommending that for the field scale, the methodology for quantifying the efficiency of agricultural water use include the collection of necessary information to calculate several suggested interrelated indicators. Collectively, these indicators have the opportunity to provide valuable information to the local user and the associated agricultural water suppliers. To the extent any indicators are reported in any manner beyond the field or supplier level, they may also provide insight and understanding to regional, state and federal policy makers.

But more importantly, these indicators cannot be viewed in isolation from one another. Each indicator suggested below allows an understanding of an aspect of the performance of a unique irrigation system – but does not provide the entire picture when the multitude of irrigation system operation and management considerations are taken into account.

The discrete data inputs DWR staff recommends collecting would be those needed to calculate:

- *Irrigation system distribution uniformity* (DU) – this indicator defines how well a particular irrigation system and the management of that system can distribute water across the field. However, simply having a high DU does not reflect the fact that a field may be over or under-irrigated in relation to the water required to optimally produce a crop year after year.



Furthermore, different irrigation systems and management practices have different potential DU values and no system and management can be 100% uniform.

$$DU = \frac{\textit{Average Low Quarter Depth of Water Applied to Plants in a Field}}{\textit{Average Amount of Water Applied to Plants}} \times 100$$

As a general consideration, the figure below indicates how an improvement in DU has the capacity to allow for the amount of water applied to more closely match the ideal quantity

$$DU = \frac{\textit{Average Low Quarter Depth of Water Applied to Plants in a Field}}{\textit{Average Amount of Water Applied to Plants}} \times 100$$

needed for agronomic purposes (Irrigation efficiency in this instance relates to the single irrigation event's relationship between water applied and the "beneficial needs" of the crop at the time of the event.

DU is typically determined using this formula, where the amount of water supplied to the "low quarter" represents the area of a field receiving the least amount of water compared to the rest of the field being irrigated at that time.

DU is a helpful indicator of the performance of a system and the management of that system to help manage water at the field scale.

- *Consumptive use fraction* (CUF) – this indicator, defined as the ratio of ET of applied water divided by the quantity of water delivered to the field, is likely the best representation for what many may believe is the classic definition of "efficiency." This indicator, however, does not account for water applied for salt management, cultural practices or other uses not related to the Crop ET. The CUF has the ability reflect the relative potential a given field irrigation system may have to a chosen conservation measure.

- *Fraction that incorporates other agronomic or reasonable uses.* An extension of the CUF would account for agronomic and other uses beyond simply crop consumptive use. An example of such is a fraction is *irrigation sagacity* (IS)– which incorporates agronomic uses such as salt leaching and frost protection, but also allows for the recognition of uses of applied water for meeting water quality requirements (e.g. in tailwater/tilewater drains), realistic irrigation system performance limitations, as well as reasonable accommodations for an irrigation system operators tendency to err on the side of caution (e.g. a little over application to ensure soil salts are managed – a "safety factor"). The figure to the right represents the relationship between traditional *Irrigation Efficiency* and *Irrigation Sagacity*.

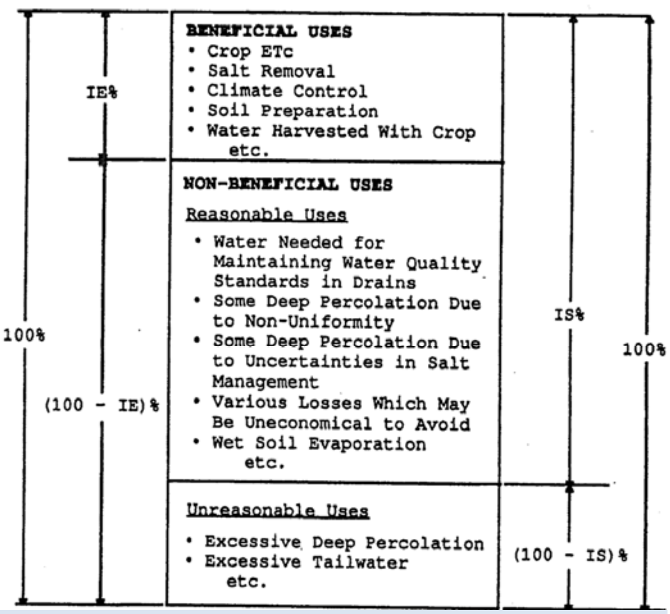


Figure: Representation of the relationship between Irrigation Sagacity and Irrigation Efficiency (source: C.M. Burt (et al), *Irrigation Performance Measures: Efficiency and Uniformity*, Journal of Irrigation and Drainage Engineering, Nov/Dec 1997.

In addition to the indicators listed above, the information gather to perform the related calculations may also allow for the determination of additional field scale indicators such as:

- Reusable Fraction and Non-reusable Fraction
- Effective Irrigation Efficiency (E_e)
- Productivity per Acre-foot (aka "crop-per-drop")

However, calculating these indicators may require additional data inputs not otherwise necessary for the primary indicators.

What other indicators could be used instead of or in combination with the primary three listed? Discussion: There is no one universal indicator of the efficiency of agricultural water use at this level. The indicators currently selected intend to provide a range of valued information to the irrigator and the water supplier to be used as appropriate to assure sustainable farming practices.

2.3.2 Field Scale Data Inputs and Collection

The emphasis of this proposed methodology is on the collection of the data inputs necessary to calculate the desired indicators. The data inputs for each indicator include:

- Irrigation System Distribution Uniformity – [to be added]
- Consumptive Use Fraction – [to be added]
- Irrigation Sagacity - [to be added]

2.3.3 Field Scale Data Collection Temporal Scales

The collection of data necessary to quantify the field scale efficiency of agricultural water use needs to have a defined temporal scale for each indicator. For the indicators previously listed, DWR staff recommends that data be collected to represent:

- For *Irrigation System Distribution Uniformity*, data would be collected relating to one individual irrigation event. The re-evaluation of the same system for a different event would allow a local user to evaluate the effect of any system, management or operational changes implemented since the previous evaluation, providing direct feedback. Ideally, evaluations could be undertaken every few years for the same field to allow for continuous opportunities to maintain high values or to make changes to improve less than optimum values.
- For *Consumptive Use Fraction*, data would be collected for either (a) the complete irrigation season (including any pre-irrigation activities related to a growing season) or (b) the entire year, if multiple crops were grown on the field. The resulting information could provide guidance as to the potential change that could result from implementing certain changes to irrigations systems, operations or management.
- For *Irrigation Sagacity*, data would be collected for either (a) the complete irrigation season (including any pre-irrigation activities related to a growing season) or (b) the entire year, if multiple crops were grown on the field. The resulting information could provide guidance as to the potential change that could result from implementing certain changes to irrigations systems, operations or management.

Does the methodology to collect defined data for the three suggested indicators provide a range of information that meets the intent of quantify the efficiency of agricultural water use at this scale?

Should other time-scales for data collection be included?

Who should primarily collect and maintain data at the field scale?

To what extent can or should existing methodologies and data be relied upon for the methodology at each spatial scale? For instance, could an on-farm scale methodology use the methodology developed and used by the Mobile Irrigation Lab services previously funded by DWR and U.S. Bureau of Reclamation (and often operated by Resource Conservation Districts)?

2.4 Agricultural Water Supplier Scale Proposal

At this spatial scale, DWR staff is suggesting Option 3 be used to define the methodology. This option is being chosen for several reasons:

- The water management activities that occur within the boundaries of an agricultural water supplier can include a) multiple levels of reuse among irrigated fields, b) providing water for environmental objectives or regulatory requirements, and c) promoting dynamic field scale management to facilitate conjunctive use operations.
- Field scale indicators cannot be summed to indicate the efficiency of agricultural water use at this scale.
- In some instances, agricultural water suppliers do not control all of the water used within their boundaries, especially as a result of groundwater pumping by private wells. However, operations of a supplier often affect the groundwater conditions, especially if planned over-application or other activities are undertaken or encouraged to facilitate conjunctive management objectives.

2.4.1 Agricultural Water Supplier Scale Indicators

DWR staff is recommending that for the agricultural water supplier spatial scale, the methodology for quantifying the efficiency of agricultural water use include the collection of necessary information to calculate two indicators:

- *Agricultural Water Supplier Consumptive Use Fraction* [*appropriate term to be developed*] – This indicator reflects the resulting fraction from comparing the ET of water applied across all fields within the service area of the supplier to the total water applied to the fields associated with the water under control of the agricultural water supplier. Because this value could vary significantly on a year-to-year basis due to such factors as limitations in water availability or management of annual surplus supplies, the indicator would be a dynamic value average over multiple years. As an example, a water supplier may provide 1,000 units of water to meet 600 units of ET in Year 1, with a portion of the "overage" intended to percolate into the groundwater basin for future use. In Year 2, the supplier only has 500 units for the same 600 units of ET, with private pumping extracting the "overage" stored from the previous year. To make this indicator valuable, the values must be averaged over time.

- *Agricultural Water Supplier Water Management Fraction* [*appropriate term to be developed*] – This indicator would allow a water supplier to remove from the indicator above any water that is directed toward inter-seasonal water management, such as groundwater recharge through managed deep percolation. Using the above example, the volume of water deemed to be stored in the aquifer from Year 1 as a result of managed percolation, would be subtracted from the total applied in Year 1 to meet the demands of Year 1.

2.4.2 Agricultural Water Supplier Scale Data Inputs and Collection

[to be developed based on the indicators chosen]

2.4.3 Agricultural Water Supplier Scale Data Collection Temporal Scales

[to be developed based on the indicators chosen]

2.5 Regional Scale Proposal

At this spatial scale, DWR staff is suggesting Option 2 be used to define the methodology. This option is being chosen for several reasons:

- The use of water within a regionally defined boundary has many discrete actions occurring that individually may or may not be optimal methods of using water to meet the needs of a particular field or agricultural water supplier. But, due to the broad degree of reuse as water flows between fields and from one agricultural water supplier to another, the interrelationships of surface water and groundwater sources within the regional boundaries, and regional inter-annual storage (ground or surface), only the net movement into and out of the defined boundary makes sense
- Regional scales include the entire available aquifer as part of its defined boundary condition.

2.5.1 Regional Scale Indicators

DWR staff is recommending that for the regional spatial scale, the methodology for quantifying the efficiency of agricultural water use include the collection of necessary information to calculate one primary indicator:

- [to be developed, but will likely match the concepts presented in the California Water Plan Update 2009]

2.5.2 Regional Scale Data Inputs and Collection

[to be developed based on the indicators chosen]

2.5.3 Regional Scale Data Collection Temporal Scale

[to be developed based on the indicators chosen]

3.0 Report to the Legislature

The legislation also requires the report to the Legislature to include an implementation plan for the methodology and an estimate of the cost to implement. DWR staff does not intend that the report will assign implementation responsibility and cost to specific entities (such as DWR or the water supplier). The report may, however, recognize that different data gathering and calculation activities can be implemented effectively and efficiently by different entities. For instance, for quantification at the field scale, the local water supplier may be the most cost-effective entity to collect data. In contrast, a regional scale quantification methodology could involve a combination of entities, including DWR, water suppliers, and the U.S. Bureau of Reclamation.

Should the implementation plan recommend the entities that should be the primary collectors of data?

Quality control of data collected for each spatial scale methodology will be an important part of the methodology. Who should be charged with quality control planning, training and implementation? For instance, DWR historically funded systematic quality control by an independent entity. Should the level and method of quality control vary for each spatial scale methodology developed?

The legislation requires DWR to include "estimated implementation costs" in the plan submitted to the legislature. In this context, what cost components are necessary to estimate cost of implementation (e.g. data collection, compilation and assessment; quality control)? Specifically, are there local implementation costs that might be imposed on water suppliers or growers that DWR should be sure to consider?