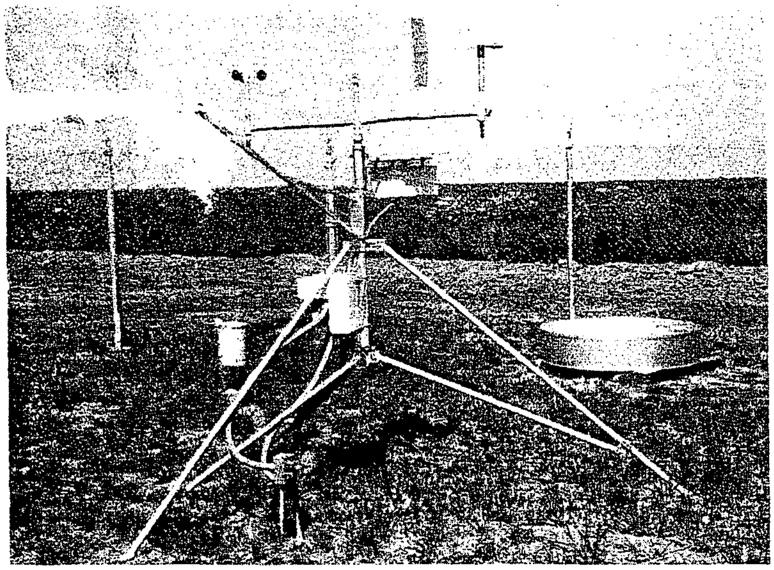

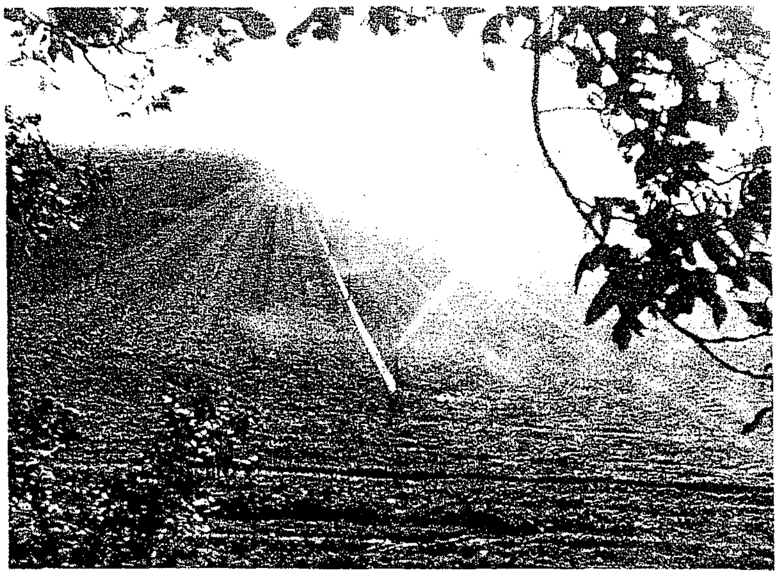

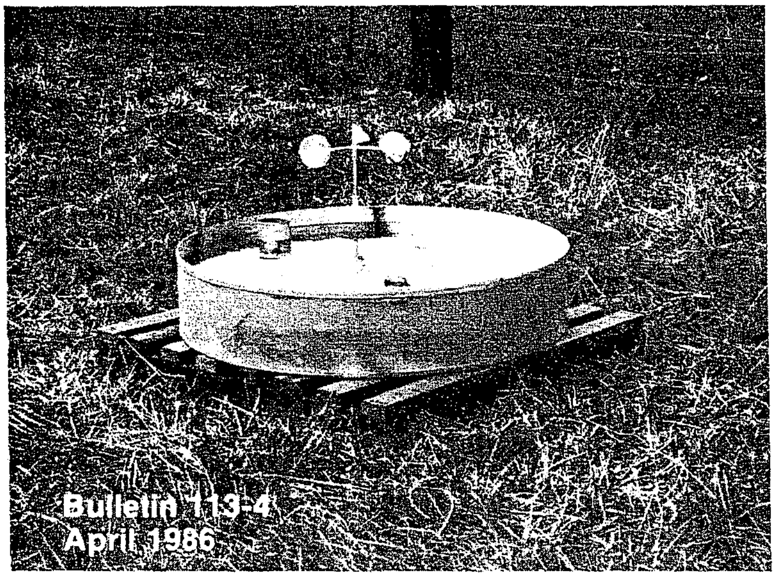

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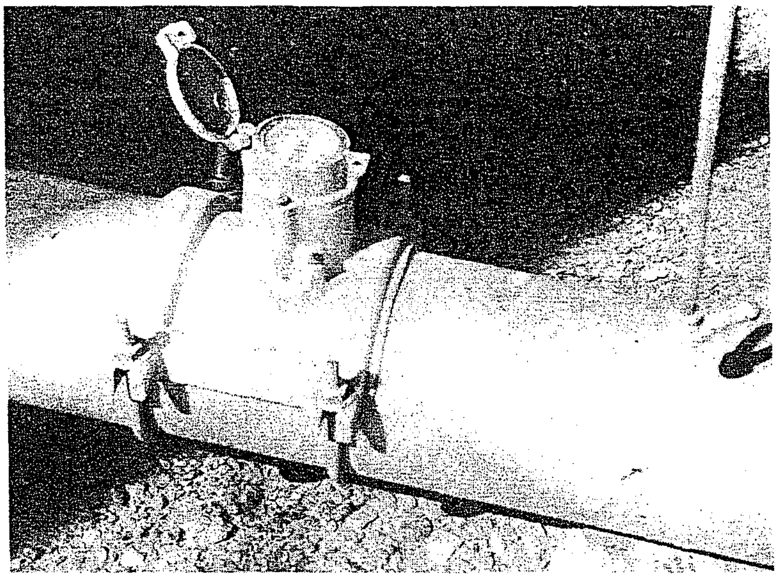

State of California
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Department of
Water Resources

Crop Water Use in California

Gordon K. Van Vleck
Secretary for Resources
The Resources Agency

George Deukmejian
Governor
State of California

David N. Kennedy
Director
Department of Water Resources

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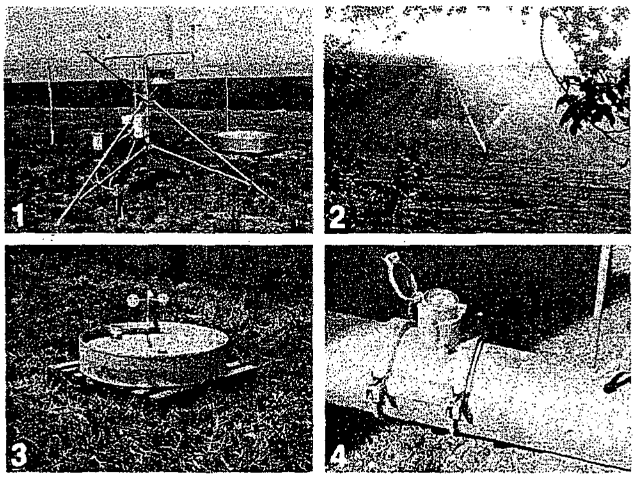

ON THE COVER: (1) California Irrigation Management Information Service (CIMIS) station in the Central Valley (see Chapter III). (2) Sprinkler-irrigated alfalfa field in the Sacramento-San Joaquin Delta. (3) U. S. Weather Bureau Class "A" evaporation pan with anenometer, installed in a standard-environment irrigated pasture. (4) In-line low-pressure flowmeter used to measure applied water (see Appendix C).

Department of
Water Resources

Bulletin 113-4

Crop Water Use in California

April 1986

Gordon K. VanVleck
Secretary for Resources

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Director

The Resources Agency

State of California

Department of Water Resources

JOHN W. SHANNON
1913 - 1981

This publication is dedicated to the memory of the late John W. Shannon.

John Shannon was a member of the team that produced Bulletin 2, "Water Utilization and Requirements of California," in 1955, and Bulletin 3, "The California Water Plan" in 1957. Those two publications, along with Bulletin 1, "Water Resources in California" (1951) have been the foundation for most State water planning ever since that time. John Shannon took the lead in developing programs and a technical staff directed toward the establishment of practical scientific procedures for estimating and monitoring crop water use in California.

John's efforts led to the development of the data collection and analysis procedures discussed in this bulletin. For those accomplishments he attained the high esteem of his associates in both the Department and the entire scientific community.

It is fitting that we take this opportunity to honor a man whose dedication and abilities have had such lasting impacts on the activities of the California Department of Water Resources.

FOREWORD

The Department of Water Resources has a continuing program for collection and analysis of crop-water-use and related data, such as measurements of climate and soil moisture. This information provides the basis for estimating per-acre evapotranspiration of water and the quantities of water applied by irrigation. Bulletin 113-4, the fourth in a series of Department publications presenting such data, reports the data collected during 1973 through 1983.

With ever-increasing attention being directed toward agricultural water use, the Department considers it important that as much relevant data as possible be made available to all concerned. It is also important that those who use the data understand the reasons for the variations in water use shown by the data. Therefore, the bulletin also includes considerable discussion of the factors that influence crop evapotranspiration and irrigation practices in California.

David Kennedy

David N. Kennedy, Director
Department of Water Resources
The Resources Agency
State of California

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GEORGE DEUKMEJIAN, Governor

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ROBERT W. JAMES
Chief Counsel

DIVISION OF PLANNING

Arthur C. Gooch . . . . .Chief
Donald J. Finlayson . . . . Chief, Planning Branch

This bulletin was prepared under the direction of

Glenn B. Sawyer . . . . .Chief, Land & Water Use Section

by

Clyde K. Muir . . . . .Associate Land & Water Use Analyst, Northern District

With major contributions by

Richard J. Wagner . . . . . .Senior Land & Water Use Analyst, Division of Planning
Robert R. McGill. . . . . Senior Land & Water Use Analyst, Northern District
George K. Sato. . . . . .Senior Land & Water Use Analyst, Central District
Richard A. Cocke. . . . . Associate Land & Water Use Analyst, Central District
John E. Morris. . . . . Associate Land & Water Use Analyst, Central District
Eugene M. Pixley. . . . . . .Associate Land & Water Use Analyst, Northern District
Frederick E. Stumpf . . . . .Senior Land & Water Use Analyst, San Joaquin District
Norman A. MacGillivray . Associate Land & Water Use Analyst, San Joaquin District
David L. Scruggs. . . . . Associate Land & Water Use Analyst, San Joaquin District
John A. Tenero. . . . . Senior Land & Water Use Analyst, Southern District
David A. Inouye . . . . . . .Associate Land & Water Use Analyst, Southern District

Editorial and Production Service provided by

Earl G. Bingham . . . . .Research Writer, Division of Planning

Word Processing by

Clara Silva . . . . Word Processing Technician

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Most of the data presented in this bulletin were obtained through the cooperative efforts of many individuals too numerous to list. Overall, the data were largely furnished by employees of federal, state, and county agencies; irrigation and water districts; and interested growers.

The Department of Water Resources and the author gratefully acknowledge the assistance received from these many individuals. We would also like to thank the many landowners who provided us with long-term free access and use of their acreages for the installation and operation of climatological and water-measuring equipment.

Unless otherwise indicated, all photographs were provided by the Land and Water Use Section of the Division of Planning.

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The California Water Commission serves as a policy advisory body to the Director of Water Resources on all California water resources matters. The nine-member citizen commission provides a water resources forum for the people of the State, acts as a liaison between the legislative and executive branches of State Government, and coordinates Federal, State, and local water resources efforts.

CHAPTER I. INTRODUCTION

This is the fourth in a series of Bulletin 113 reports presenting data and estimates of crop evapotranspiration (ET) and applied (irrigation) water rates. The information, when combined with data on the acreage of specific crop production, provides knowledge of the location, nature, and amount of water use throughout the State. Such information is required for many different Department studies, including those conducted to determine (1) developing water supply shortages or the availability of water supply for local use and/or export to other areas of need; (2) the ability of users to pay for additional water supplies; (3) optimum reservoir operations; (4) the rate of ground water extractions; (5) the potentials for water savings through increased water use efficiency; (6) the location, nature and amount of water quality deterioration due to agricultural chemicals; (7) current and potential soil water drainage problems; and (8) other water resource-related matters.

Bulletin 113, "Vegetative Water Use Studies," (1963) presented crop ET and related climatic data collected and analyzed during 1954-1960; Bulletin 113-2, "Vegetative Water Use," (1967) extended the data set through 1964, and Bulletin 113-3, "Vegetative Water Use in California," (1975) presented data collected and analyzed through 1972, and described methodologies that are still used in such studies. It is recommended that Bulletin 113-3 be used as a reference for explanations of methods of data collection and analysis not explicitly described in this report (Bulletin 113-4).

The Department has continued to measure crop evapotranspiration, focusing on crops for which values had not been determined by 1972. Others have also measured crop ET. Agroclimatic stations have continued to provide the climatic data necessary for relating measured crop ET rates from sample sites to the rates at other locations.

In addition, the Department has given special attention to improving its crop unit applied-water data base. Meters and other measuring devices have been installed and monitored, and considerable effort has been given to locating and analyzing data measured by others.

Increasing attention is being given to agricultural water use, irrigation efficiencies, and the potential for stretching the beneficial use of developed agricultural water supplies. Therefore, in addition to reporting data acquired since the previous edition of this bulletin (113-3), this report attempts to (1) describe the nature of irrigation practices commonly followed in California, and (2) discuss the factors influencing those practices. Its purpose is to promote a better understanding of agricultural water use among those who have only a passing knowledge of the subject but who are interested in current agricultural water supply issues.

Specifically, this report presents summaries of data collected from 1973 through 1983, discusses factors that influence applied water rates, presents estimates of county average crop unit applied water, and provides instructions for installing agricultural water meters, establishing agroclimatic stations, and operating 1-gallon evaporimeters, and other information. Topics discussed and data provided include:

- Factors that influence the frequency and amount of irrigation water applied to crops, methods of measuring applied irrigation water, estimates of average applied water rates in large areas, and estimates of countywide averages of irrigation water applied to crops during 1980. (Chapter II)
- Methods of determining crop evapotranspiration, including direct measurements using lysimeter tanks, and estimates of ET from Class "A" evaporation pans (Chapter III).
- A bibliography (Appendix A).
- A glossary of terms (Appendix B).
- Criteria for installing water meters and for evaluating existing installations (Appendix C).
- The siting and operation of an agroclimatic station, where climatic data are measured, i.e., solar radiation, air temperature and humidity, wind, pan evaporation, and rainfall (Appendix D).
- The one-gallon can evaporimeter, which the Department developed for special applications (Appendix E).
- An index to agroclimatic stations in California (Appendix F).
- Selected evaporation pan data (Appendix G).
- Summaries of measured data on irrigation water applied to specific crops in various parts of California (Appendix H).
- The Class "A" evaporation pan bird repeller, developed to eliminate the problem caused by birds and rodents drinking from the pans at agroclimatic stations (Appendix I).
- Ratios for adjusting (a) pan evaporation and (b) ETo (reference crop evapotranspiration from California Irrigation Management Information System) to crop ET; crop ET measurements; and ET test plot environments (Appendix J).

CHAPTER II. CROP APPLIED WATER

Introduction

Average measured applied water rates are presented in Appendix H (see Tables H-1 through H-31). This chapter (1) reviews the main factors that influence the frequency and amount of irrigation water applied, (2) describes methods of measuring applied irrigation water, (3) describes the Department's data collection program, (4) discusses factors to consider in estimating average rates for large areas, and (5) presents estimates of countywide averages of irrigation water applied during 1980.

The physiological factors of plants, the physical and chemical factors of soils and water, and climatic factors that influence soil-water-plant-climate relationships must be understood in order to understand crop water use. An understanding of both crop water use and the operation of irrigation systems helps in the understanding of why crop applied water requirements vary considerably from farm to farm and in different parts of the State. The effectiveness of rainfall, a high water table, and irrigation can be different from field to field, crop to crop, farm to farm, and region to region within the State. Methods of management of those three sources of water for supplying soil moisture for plant use have been improving in recent years.

Factors Affecting Applied Water Rates

The basic factors discussed in the following paragraphs, all of which determine crop applied water rates, can be categorized as follows: (1) climate (and climate modification practices), (2) soil, (3) the crop, (4) water price, (5) irrigation system, and (6) system operation and irrigation scheduling. In turn, each factor has a variety of conditions that may be present within every region. As a result, a multitude of different combinations are possible everywhere. A summary of some possible conditions for each of the basic factors follows, along with discussions of farm irrigation efficiency compared to water district irrigation efficiency, and drought impacts on applied water rates.

Climate

Climate impacts applied water rates by its effect on the rate of crop evapotranspiration and through precipitation's contribution toward crop water needs. In addition, irrigation applied to control the effect of extreme cold or hot temperature may add to the total amount of water applied.

Evaporative Demand. Evaporative demand is the collective influence of all climatic factors, such as solar radiation, wind, air temperature, and humidity, on the rate of evaporation of water. DWR measures evaporative demand primarily with Class "A" evaporation pans. When possible, the pans are located in a field of healthy full-cover grass, never short of soil moisture and kept clipped to a 3- to 6-inch height within the station enclosure. Research has demonstrated that evaporative demand serves as a good index to ET and, therefore, applied water requirements.

DWR Bulletin 113-3 ("Vegetative Water Use in California," 1975) presented a plate showing statewide variations in evaporative demand. Average annual evaporative demand along the north coast is about 35 inches. This increases to about 45 to 55 inches in many interior mountain valleys where elevations range from 2,000 to 5,000 feet. The hot Central Valley rate is about 65 inches. The southeast desert has the highest annual rates, which exceed 100 inches.

Localized differences occur along the upwind edge of irrigated crop fields bordered by dry nonirrigated fields. Evaporative demand can be 40 percent higher along that edge due to advection (movement) of relatively warm, dry air from the nonirrigated areas. In some cases evaporative demand is greatly reduced and equilibrium reached under light wind conditions after the passage of air over 200 feet of full crop cover (about 50 to 80 percent cover or more). However, to reach equilibrium under strong wind conditions, more than 500 feet of fetch has been demonstrated to be a minimum distance to reach equilibrium. Additional irrigation water is needed by the crop growing within this advection zone. Figure D-3 (in Appendix D) shows how advection affects evaporative demand as warm, dry air enters a field of grass turf.

Precipitation. Most agricultural areas in California receive too little rain to sustain crops. In areas of the State where mean annual rainfall exceeds 20 inches, rainfall may be the total water supply used to grow certain crops such as small grains and grapes. However, in most areas, rainfall alone is inadequate in amount and in timing to produce an adequate crop yield. In addition, rainfall occurrence is a random event, and its timing and amount cannot be forecast accurately.

The purpose of irrigation is to correct a deficiency in the amount and timing of precipitation. Even with a full soil profile at the beginning of spring, a lack of spring rain would soon allow soil moisture to be depleted by crop evapotranspiration, and irrigation would be required sooner than normal. On the other hand, even below-normal annual rainfall, if properly timed, i.e., occurring during the spring growing season, can reduce irrigation needs.

Long-range weather forecasts (exceeding 5 days in duration) are sometimes ineffective in providing accurate information for irrigation scheduling. As a result, irrigations may be applied, only to be followed by unexpected or unexpectedly heavy rainfall. Whether the irrigation or the rain is wasted is a moot point. More accurate weather forecasts could greatly enhance the effectiveness of irrigation scheduling.

Much of the southern San Joaquin Valley floor receives less than 8 inches of annual precipitation. Monthly precipitation is generally exceeded by monthly ET by weeds and evaporation from bare soil so that little winter rainfall is carried over into the growing season. Therefore, orchards and vineyards are often irrigated during winter in preparation for spring bloom and leaf-out, and annual crops are preirrigated.

Climate Modification. Irrigation is used in some locations to modify weather that would otherwise be damaging to crops. Water can protect crops against both excessive cold and heat, although the amount of water so used is small compared to that applied to meet ET.

Surface and sprinkler irrigation can be used to protect against frost. Moist, barren soil absorbs a significant amount of solar radiation, which is released as heat at night.

Irrigation by sprinklers protects against frost in two ways: (1) by the warming caused by the temperature of the water and (2) by the heat released as water freezes. The natural heat contained within water provides protection against light frosts. Ground water works well for this purpose. Ground water temperatures in most fruit-production areas are generally about equal to the mean annual air temperature. Mean annual air temperature typically exceeds 56 degrees F in most tree- and vine-growing areas of California.

The water continuously applied to plant parts during a heavy frost releases heat as the water freezes. The continuous release of heat from the freezing of water applied to plant parts keeps the ice temperature at 32 degrees F. Ice at 32 degrees F insulates the plant against air temperatures even though they may be in the 20s.

Although the sight of ice on a crop may look damaging, light applications of water (about 0.1 inch per hour) from an impact sprinkler turning at least 1 revolution per minute are considered ideal. A continuous light application of water is needed to maintain a water-ice interface while minimizing the chance of limb breakage.

As water is applied by sprinklers, the air is cooled. This is used to provide cooling to certain crops during periods of high temperatures, which could reduce yield or crop quality.

Unseasonably warm spring weather can cause fruit tree buds to form and open too early. Early blossoming is susceptible to frosts, which are still likely to occur. Intermittent operation of sprinklers during warm afternoons cools the air and can delay bloom for up to two weeks. Leaf temperatures during hot summer days can be lowered by about 25 degrees F during sprinkling under conditions of wind and low (15-20 percent) relative humidity.

In some cases, a portion of the water applied for climate modification is subsequently stored in the soil and is available for crop ET.

Soil

Because of a wide range of topographic features, land forms, and climates,

A sprinkler can be used to delay blossoming of trees in early spring, thus protecting them from late-season frosts, and to lower leaf temperatures on hot summer days.

California has hundreds of soil types. Each soil type has at least one physical or chemical feature that sets it apart from others.

The amount of water a soil can store that is available for extraction by plants is determined largely by the physical and chemical properties of the soil and the extraction properties of the plant. Depth, texture, structure, excessive salt, and organic matter content are the most important soil physical properties.

Generally speaking, fine-textured soils have the highest moisture-holding capacity. Therefore, frequency of irrigation can be minimal. The reverse is true for coarse-textured soils. They retain relatively little water against the pull of gravity. Therefore, more frequent irrigations, which may contribute to relatively high applied water rates, are necessary.

The rate of water movement through soil is important. Generally, fine-textured soil transmits water slowly, and coarse-textured soil transmits water rapidly. These features are important to the design and operation of an irrigation system. An improperly designed or operated surface irrigation system could cause an excessive loss of irrigation water to deep percolation or runoff. Sprinkler or drip irrigation is preferable on sandy soils in some cases, because the excessive deep percolation common to coarse-textured soils can be controlled more easily with these systems.

Due to the low infiltration rate of clay-loam soils, level fields are well suited to surface irrigation because they usually require a prolonged period of water application.

High-Water Table. The effect of a high-water table on a crop can be beneficial in some situations and damaging in others. The characteristics of a high water table and the soil type dictate what crops can be grown, the type of irrigation system used, and the amount of water applied for irrigation. A beneficial water table supplies all or part of a crop's ET requirement. Also, it should not adversely affect the soil oxygen supply nor should it contribute excessive amounts of salt to the plant-root zone. It may have a constant depth or a depth that can be controlled. A water table with a constant depth supplies water to a crop via its capillary fringe. The capillary fringe rises above the zone of saturation due to adhesive forces with the soil particles, with water pulled higher above the water table in a loam soil than in a sandy soil. Very importantly, the capillary fringe contains air, whereas the air content of a water table is inadequate to allow normal root functioning.

An ideal high-water table is one that can be controlled. It can be allowed to rise and remain in the root zone just long enough to provide an irrigation, and then allowed to drain away to provide aeration of the roots. This type of irrigation is very successful in the Sacramento-San Joaquin Delta.

A water table that is too high can have many undesirable effects. In the spring, wet soil warms very slowly, delaying planting and access to the field. A high water table in some locations causes excess salts to wick up to the soil surface, making the soil too saline or sodic for crop production.

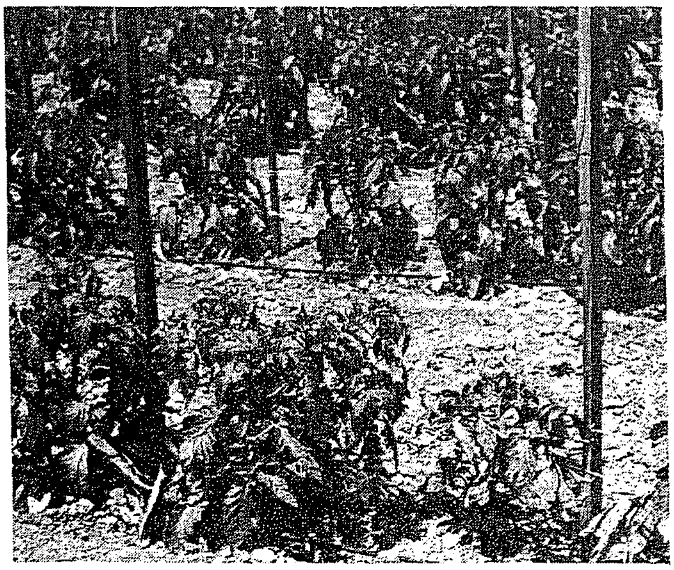
Perhaps the most common problem associated with high water tables is their anaerobic (low oxygen) condition. Plant leaves take in carbon dioxide and expel oxygen as a waste product, whereas plant roots take in oxygen and expel carbon dioxide as waste. Without an adequate oxygen supply to the roots, plant growth and crop yield diminish, and death of the plant can occur.

Certain soil-borne disease organisms can proliferate within wet soil, resulting in their attacking and seriously damaging or killing feeder roots.

Salt-Leaching Fraction. All irrigation water contains salt; the amount depends on the water source. Irrigation water that is relatively high in salinity tends to cause salts to accumulate within the soil profile. If allowed to accumulate, these salts may eventually inhibit, and may completely prevent, plant growth. If annual precipitation does not exceed about 12 inches, additional irrigation water is needed to flush the salts below the crop-root zone.

Sodium salt causes soil-particle dispersion, which seals the soil pores. This sealing greatly reduces the rate of infiltration of water and may affect the efficiency of an irrigation system. Nonsodium salts have a different effect. Excessive amounts of some nonsodium salts tend to flocculate (aggregate) soil particles, which allows the exchange of air and the infiltration of water.

Other harmful effects of salinity come from toxicity and the increased osmotic pressure of soil moisture, which makes it difficult for plants to obtain moisture even if the soil has a high soil moisture content. The result can be plant wilt, dessication, and even death. This condition requires frequent irrigation to maintain high soil moisture content.



Pole tomatoes, an annual crop, for the fresh produce market (growing near San Diego)

Artichokes, a perennial crop, near Castroville Monterey County

Excess salt within irrigation water or soil must be properly managed. This requires the application of additional water for leaching (leaching fraction), and often tile drains or drainage ditches are needed to carry away the excess salts and water.

Crop

Crops can be classified as annual (in the ground less than 12 months) or perennial (in the ground more than 12 months). Perennials are further classified as either deciduous (without leaves for part of the year) or evergreen. Generally, most annuals (e.g., sugar beets, corn, and beans) have a higher midseason monthly ET rate than do perennials (e.g., orchards, grapes, and pasture) but the seasonal total is less for annuals due to the shorter growing season.

Deciduous perennials, e.g., grapes and clean-tilled orchards, have nearly the same mid-season monthly ET rates as other perennials, such as pasture and alfalfa. However, seasonal ET is much lower for deciduous perennials because of their shorter growing season. Olive and citrus monthly ET rates appear to be about 25 percent lower than ET rates for most perennial crops.[1] Depending on the management of the irrigation system in use, applied water amounts generally vary according to crop ET.

Some crops must have high soil moisture levels to produce high yields of good quality (e.g., lettuce and white potatoes) while others can tolerate low soil moisture (e.g., cotton and safflower). Minimum soil moisture tolerance level partially determines irrigation frequency, which in turn affects the quantity of water applied.

Aerodynamically fine-textured crops (e.g., grass) normally have lower water use rates than aerodynamically coarse-textured crops (e.g., corn and sugar beets) during windy periods. Also, aerodynamically coarse-textured crops have higher ET rates, because they more effectively trap and use solar radiation. And, crops displaying light-colored leaf pigmentation use less water than dark-pigmented crops.

Rooting depth for any particular crop depends primarily on the type of plant, soil profile conditions, and availability of soil moisture throughout the soil profile. Even where the soil is deep and without adverse conditions, such as restrictive layers or a fluctuating high-water table, many deep-rooted crops extract most of the moisture needed for ET from the upper half of the root zone.

Truck crops, e.g., strawberries and tomatoes, which produce very succulent edible parts, generally extract most of their moisture from 1/4 to 1/2 of the normal rooting depth. A crop such as strawberries requires frequent light irrigations to maintain high soil moisture availability within the upper foot of soil. The importance of knowing the depth from which most of the water is extracted is that it indicates the approximate depth of water that can be stored following an irrigation; this in turn provides an indication of frequency of irrigation needed.

Another factor of rooting depth pertains to effective precipitation. Deep-rooted plants are able to make better use of deep soil moisture from precipitation than are shallow rooted crops.

Price of Water

Water prices within a region can vary within short distances, depending on the water source. Generally, water from older surface storage facilities is relatively inexpensive, and newer projects, such as the State Water Project (SWP), have relatively high-priced water. The cost of ground water depends on local conditions (mainly pumping depth). Approximately 385 water districts, commercial water service agencies, and mutual associations sell and distribute water to the agricultural sector in California. Most are one of several types of public water districts and, as such, sell water at cost to landowners within the district service area. This is also true of mutual associations.

Each water purveyor distributes water within a pricing framework based on its own policies, costs, objectives, and institutional constraints. As a result, a great number of water pricing systems currently are in use in California. Water prices range from less than $1 to nearly $300 per acre-foot (1983 prices) for some agricultural water. Very high-priced water usually has an impact on the type of crop irrigated, the amount of water applied, and the efficiency of irrigation. However, quite high irrigation efficiencies can also be found in areas of relatively low-cost water.

Irrigation Systems

Four basic types of irrigation systems

1/ These ET comparisons were derived from data in Table J-1 (Appendix J).

are in use: surface, sprinkler, drip and subsurface. Surface systems mainly consist of wild flood, border, basin, and furrow methods. Sprinkler systems consist of hand-moved aluminum pipe or plastic hose, solid set, and mechanically moved. Drip systems may be below or above ground. Subsurface systems allow a high water table to rise in the root zone.

Irrigation system efficiency depends in part on the uniformity of water application. Except for subsurface systems, all types of irrigation systems have potential for very high efficiencies. In practice, however, system efficiencies differ widely (e.g., 50-100 percent). System efficiencies primarily depend on quality of system design and construction, maintenance, and operation.

System Design. Good system design is based on consideration of water availability and quality, wind, land slope, soil infiltration and percolation rates, ET rates, and types of crops to be grown. Other considerations include depth of water tables, rooting depth (perennial crop) and rooting depth changes (annual crop), and soil characteristics within the root zone (e.g., textural changes, water-holding and water-release characteristics).

System Construction. Excellent surface-irrigation systems can now be constructed with laser land-grading equipment. Lasers provide the means for rapid, accurate grading of fields. Well graded fields promote more uniform application of water to the root zone.

System Maintenance. Proper system maintenance is essential for systems to continually apply water uniformly. Most surface irrigated fields require a touchup regrading every few years to maintain proper grades.

Sprinkler systems periodically need to have nozzle sizes checked for wear. Sprinkler systems that apply water containing sand can have nozzles and spoons eroded in less than one year. Damaged sprinklers cannot apply water as uniformly as designed; this causes some areas to be overwatered so that low application areas can be kept green.

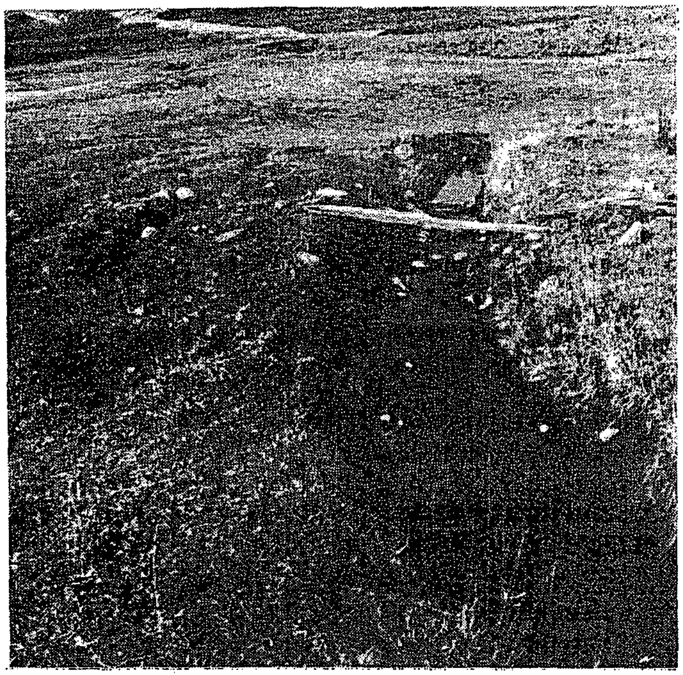
Drip systems periodically may require treatment with acid, chlorine, or other compounds to remove salt deposits and microorganisms that are clogging water delivery lines and minute drip orifices.

System Operation and Irrigation Scheduling

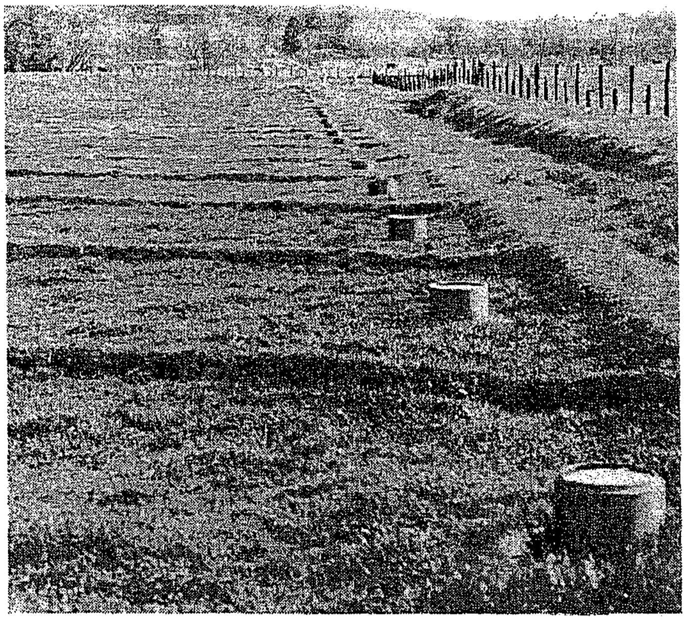
The efficient use of an irrigation system to optimize its benefits depends on a knowledgeable manager who knows his irrigation system, field soil conditions, crop development characteristics, and changing evapotranspiration rates.

Some of the specific information an irrigation manager should know includes (1) the rate at which the irrigation system applies water; (2) the total amount of water effectively applied at each irrigation (soil infiltration rate often diminishes during the season for surface irrigation); (3) the uniformity of water application; (4) average historic crop ET rates; (5) present rate of soil moisture depletion; (6) water table conditions; (7) present effective crop-rooting depth (annual crops change during the season); (8) soil water-holding and release characteristics; and (9) crop cultural practices, e.g., timing of cultivation, spraying for control of disease and weeds, and fertilizer applications.

Other factors may also be important for proper operation. For example, some portion of the water applied by a sprinkler system is evaporated from the water stream while it is airborne. High-pressure impact sprinklers, and even low-pressure spray heads, when elevated on linear or center-pivot systems, are notorious for their heavy drifts during periods of strong wind. Drifting mist from sprinklers and spray heads is not a total loss to the crop,



Wild flooding of pastureland



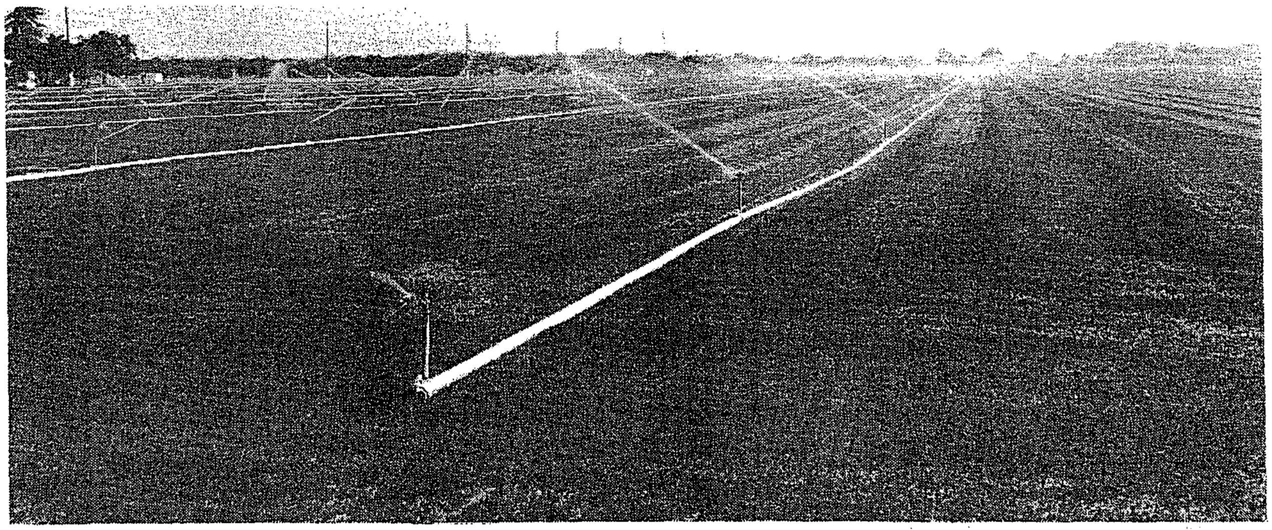
Border irrigation of pastureland. A buried concrete line with hydrants delivers water to each border strip. (Photo by U. S. Dept. of Agriculture, Soil Conservation Service)

Contour basin irrigation of rice, Sutter County

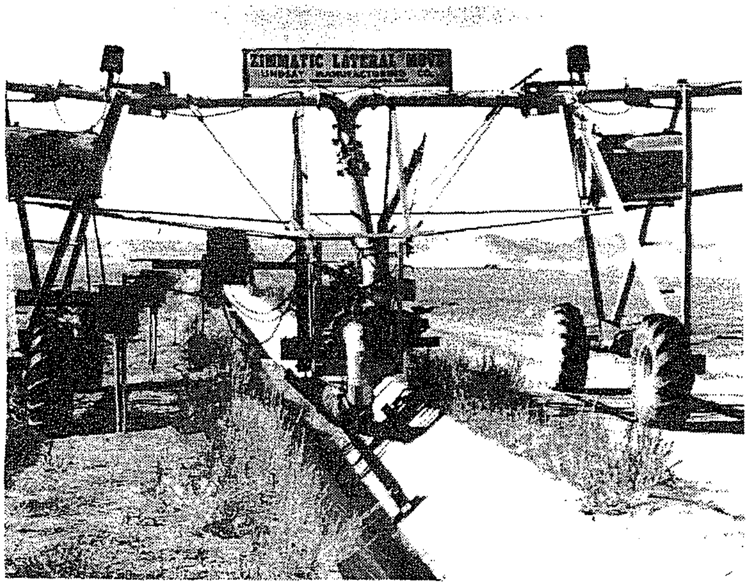
Broadbase furrow irrigation of grapes in Kern County. Water is withdrawn from an unlined main ditch via these siphon tubes.

Furrow irrigation of field tomatoes. The furrows are supplied by the gated pipe on the left.

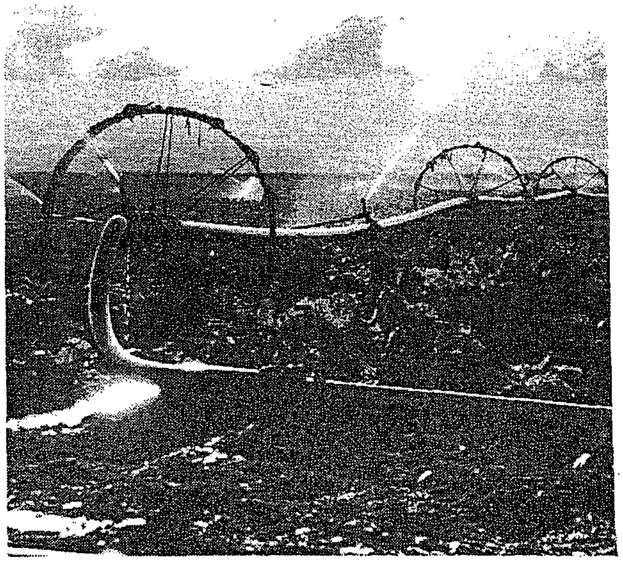
Basin check irrigation of young prune trees in the Sacramento Valley



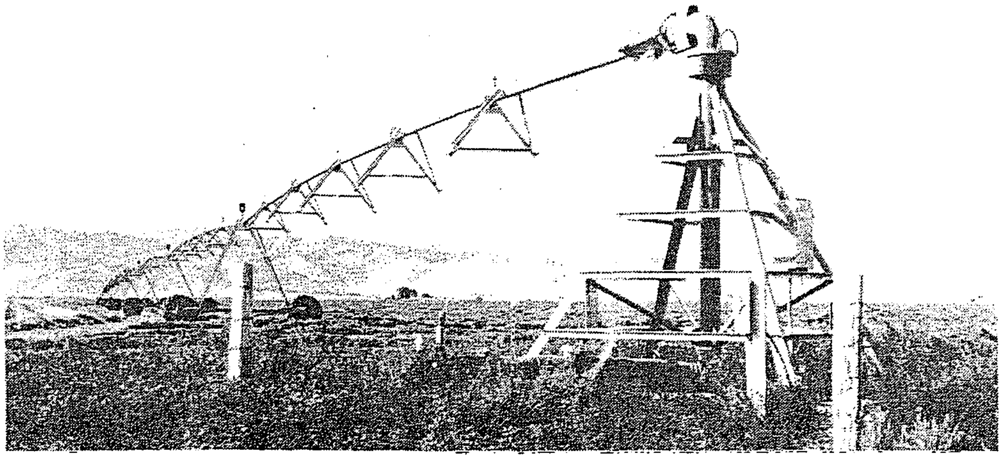
Hand move sprinklers irrigating grass turf



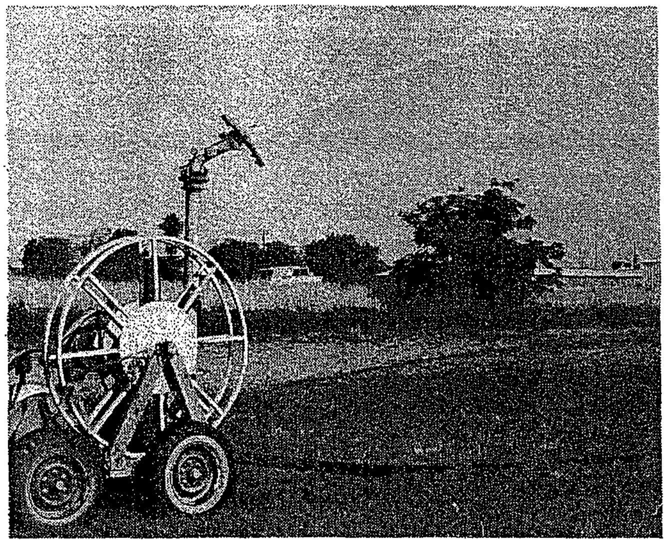
Lateral-move sprinkler system. Water is withdrawn from a ditch as the system continues across the field. The lateral is moved following each irrigation set.



Side roll, wheel move sprinklers in a field of sugar beets



Center-pivot, continuously moving sprinkler system in Sierra Valley.



Continuously moving "Big Gun Traveler" delivers a jet of water under high pressure, breaking the water stream into small droplets.

however. During the time the mist is passing over the crop downwind of the system, it is wetting the foliage and humidifying and cooling the air, thereby reducing the crop ET soil-moisture extraction rate. These effects may possibly improve crop quality and rate of growth by reducing heat stress.

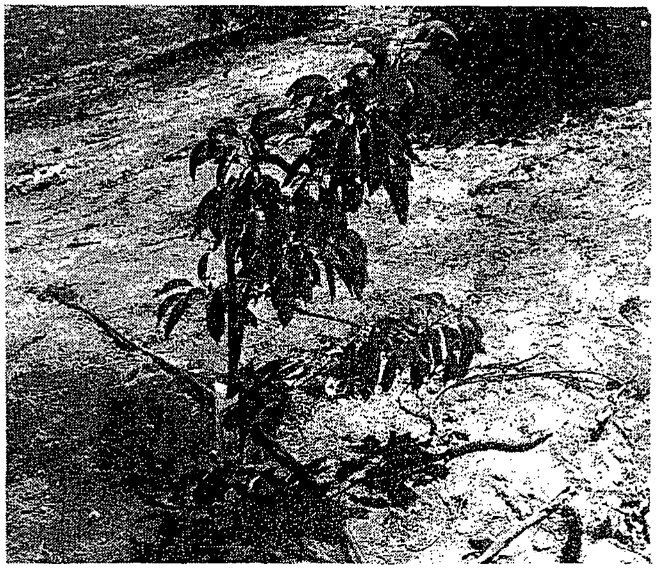
Irrigation can be scheduled to meet crop water needs effectively and efficiently by monitoring soil moisture content or by estimating crop water use based on climate and soil data. The extent to which such techniques are used often is reflective of the efficiency of irrigation and total seasonal water applied.

Soil Moisture Monitoring. Soil moisture conditions can be monitored with several devices: (1) tensiometer, (2) soil tube or auger, (3) electrical blocks, (4) pressure bomb, (5) neutron probe, and (6) others. Some of the main devices in use today are discussed below. Each device has its advantages and disadvantages.

Tensiometers function only at soil suctions (negative pressures) less than 1 atmosphere. In medium-textured soils, about half the readily available soil moisture is held at less than 1 atmosphere of suction. Therefore, tensiometer use usually results in more frequent irrigations in order to keep the soil profile moist. Although tensiometers are very effective for scheduling irrigations, growers using them to schedule irrigations may tend to have high applied water rates.

Soil samples taken by soil tubes and augers allow visual inspection of the physical condition of soils, the distribution of roots and to check for the presence of a high water table, as well as the estimation of moisture by the "feel and appearance method." This can be an effective tool for irrigation scheduling in some cases. The main disadvantage of using a soil tube or auger is that the same soil type is not necessarily being sampled each time; fields can often contain two or more soil types within a very close proximity. For instance, sampling fine-textured soils in a field containing lighter textured areas could result in incorrect decisions on when to irrigate.

Electrical resistance blocks, which are available in gypsum, nylon, fiberglass, and ceramic, are installed at each soil depth for which a moisture reading is needed. If properly installed, the blocks work best at greater than 1 atmosphere of suction. Use of these blocks allow available soil moisture to



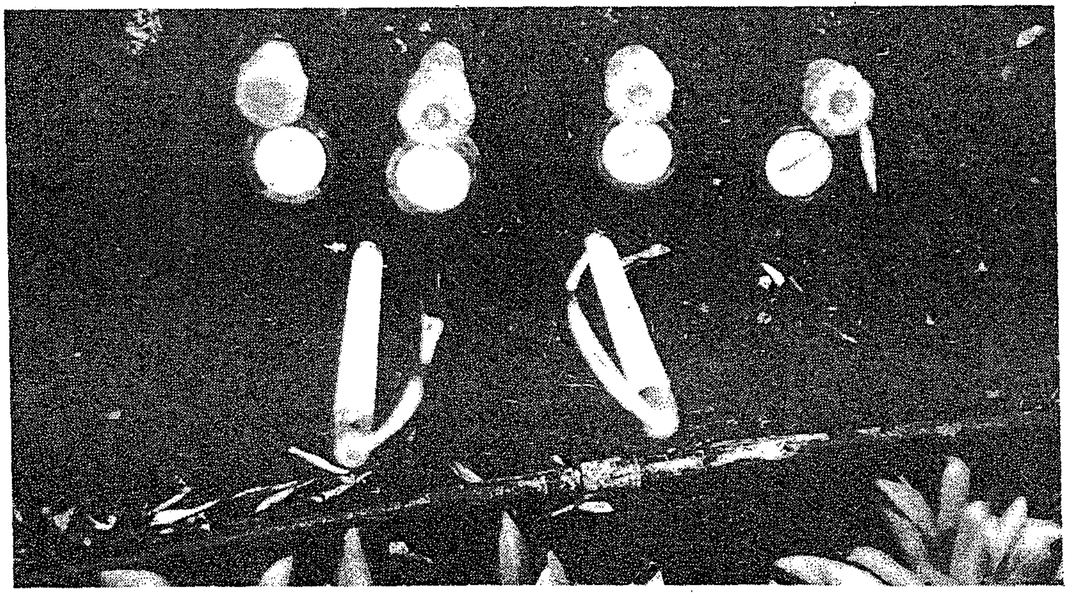
Drip irrigation of young avacado tree

be depleted to low levels prior to an irrigation.

The neutron probe provides accurate quantitative measurements of soil moisture (e.g., within plus or minus one percent for research purposes), if the access tubes are correctly installed and the probe is calibrated. A significant advantage of the probe is that readings are taken at the same soil depth position and the same soil mass each time. Any accretions or depletions of soil moisture noted are true and not due to textural changes, as may occur with gravimetric sampling at random locations. A very exact accounting of soil moisture accretion and depletion patterns is possible with this tool.

Pressure bomb operation turns the entire plant into a living tensiometer. The leaf sampled integrates all the soil-moisture stresses the plant is experiencing.

Using Climatic Data to Estimate Crop Water Use. Two indirect methods of estimating crop water use have been used successfully. Pan evaporation data have been used in California for more than 30 years to estimate ET for individual crops. Automatic electronic climatological instrumentation has been in use by the California Irrigation Management Information System (CIMIS) during the past several years at 43 locations in California. These cooperative and State-owned CIMIS stations transmit their climatological data daily to a central computer at the University of California at Davis. The central computer computes daily ET for one crop: grass turf. ET rates for other crops are determined by multiplying this ET of grass (ETo) by a factor specific to each crop. Private and government data users use their own computer terminals to extract ETo information from the central computer. This, along with the pan-evaporation-related method for estimating crop ET, is discussed further in Chapter III.



A tensiometer is used to monitor soil moisture stress at each soil depth for which a moisture reading is needed.

Farm and Irrigation System Efficiency

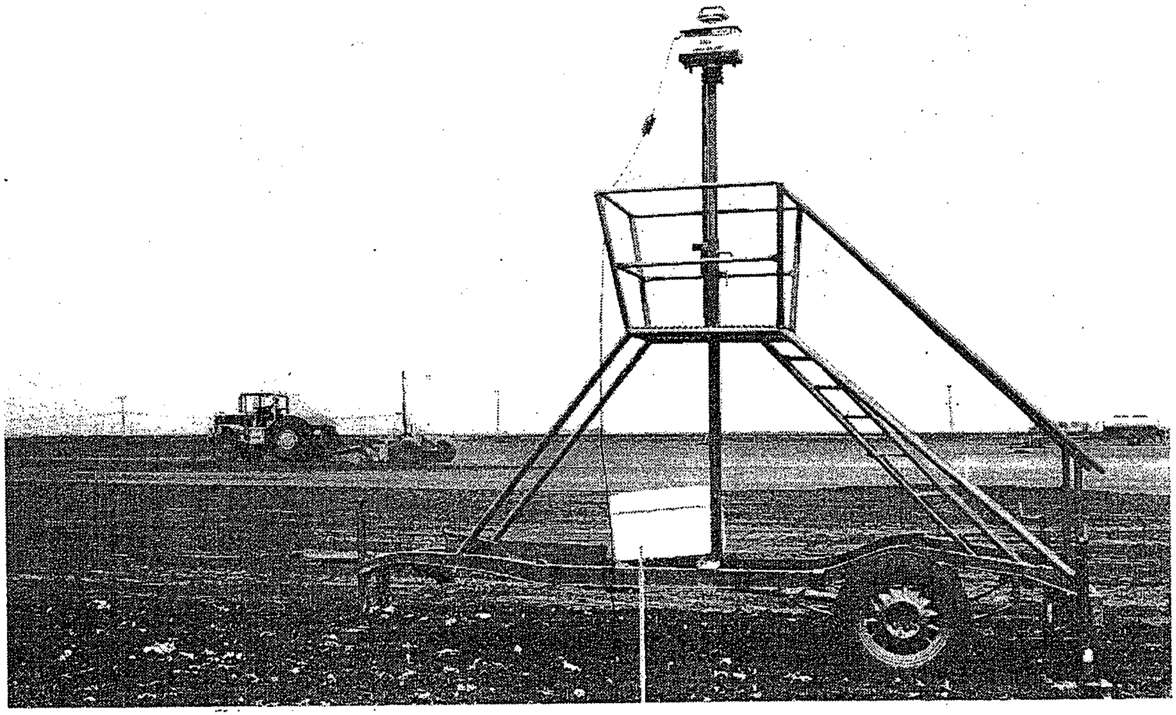
Irrigation efficiency, here, refers to the amount of irrigation water stored within the crop root zone in relation to the amount applied. Farm and irrigation district efficiency can be high even though individual field irrigation application efficiency is low.

One example of a high-irrigation-efficiency farm is one having fine-textured soils, with surface irrigation having system efficiencies averaging

Surface-irrigation return system with sump and pump, which returns the collected tailwater to the field.

50 percent but with a tailwater return system. In this case, assume that little deep percolation occurs and, therefore, most of the excess applied water is field runoff. If field runoff (tailwater) is captured and pumped back for reapplication on the same field, or if runoff is reapplied on another field on the farm, the net surface outflow from the farm, as a whole, can be very low or nonexistent. Thus, a high farm-irrigation efficiency results. If this same farm did not capture and reuse its field tailwater, it would have a low farm-irrigation efficiency.

If most of the farms within an irrigation district have a high farm-irrigation efficiency, the overall irrigation district efficiency obviously will be high. However, if most of the farms have a low farm-irrigation efficiency due to large amounts of tailwater runoff and if the district also has a large amount of runoff (outflow), the



A laser system enables fields to be graded quickly and accurately.

district then would have a low efficiency. Still, if the farms having a low efficiency provide water to downstream farms within the district, which reapply the water, the overall efficiency of the irrigation district could be high.

Increasing irrigation system efficiency may not actually lead to real water supply savings. Runoff and deep percolation of applied water often provide part of the water supply for downstream users and contribute some ground water recharge through deep percolation.

Whether a savings in water supply is attained by reducing outflow from the district's service area depends on several factors. Does the outflow go into a containment of unusable water such as a salt sink (saline ground water or the ocean)? Does the outflow represent an irrigation supply to a downstream user? Or, does it accomplish some special beneficial purpose such as satisfying Delta outflow requirements or benefiting fish and wildlife?

An example of where reductions in applied water through increased irrigation efficiency will yield water supply savings only in special cases is in California's Central Valley. Excess irrigation water in the Central Valley, other than that consumptively used by native vegetation along drains and streams, or in wetland areas, either drains back into rivers that flow to the Delta or percolates downward. During most of the irrigation season, Delta outflows are controlled to maintain water quality standards set by the State Water Resources Control Board. Under normal conditions, these required flows are such that any reduction in irrigation return flow to the Delta must be offset by increased reservoir releases. Most of the water that percolates through the soil moves into ground water basins, from which it is extracted and reused. The significant opportunity that exists for water supply saving by increased efficiency is by reduction of percolation to saline ground water.

Another example of where reductions of applied water may result in significant water supply saving is in the Imperial Valley, where excess applied irrigation water runs off into the Salton Sea. Although the sea supports a sports fishery and habitat for wildlife, this water is lost for further irrigation use. Excess inflow also causes flooding of farm and recreational lands adjacent to the sea by increasing the water level of the sea.

In some cases, even if no water supply savings would result from increasing irrigation efficiency, it may be justified from a water quality standpoint.

Drought Effects

Applied water requirements throughout most of California are affected considerably by variation in seasonal and annual precipitation. Normal season rainfall at most California locations occurs during October through April, with the peak occurring during December and January. Most rainfall, therefore, occurs during the coldest time of year, when evaporation and plant water use are lowest. A large portion of the precipitation in excess of current evapotranspiration is stored within the soil profile for later use by crops. Evergreens and winter hardy annuals make the best use of this rainfall pattern. Depending on the amount of winter rain received, winter-grown annual crops may require some additional water before the spring harvest.

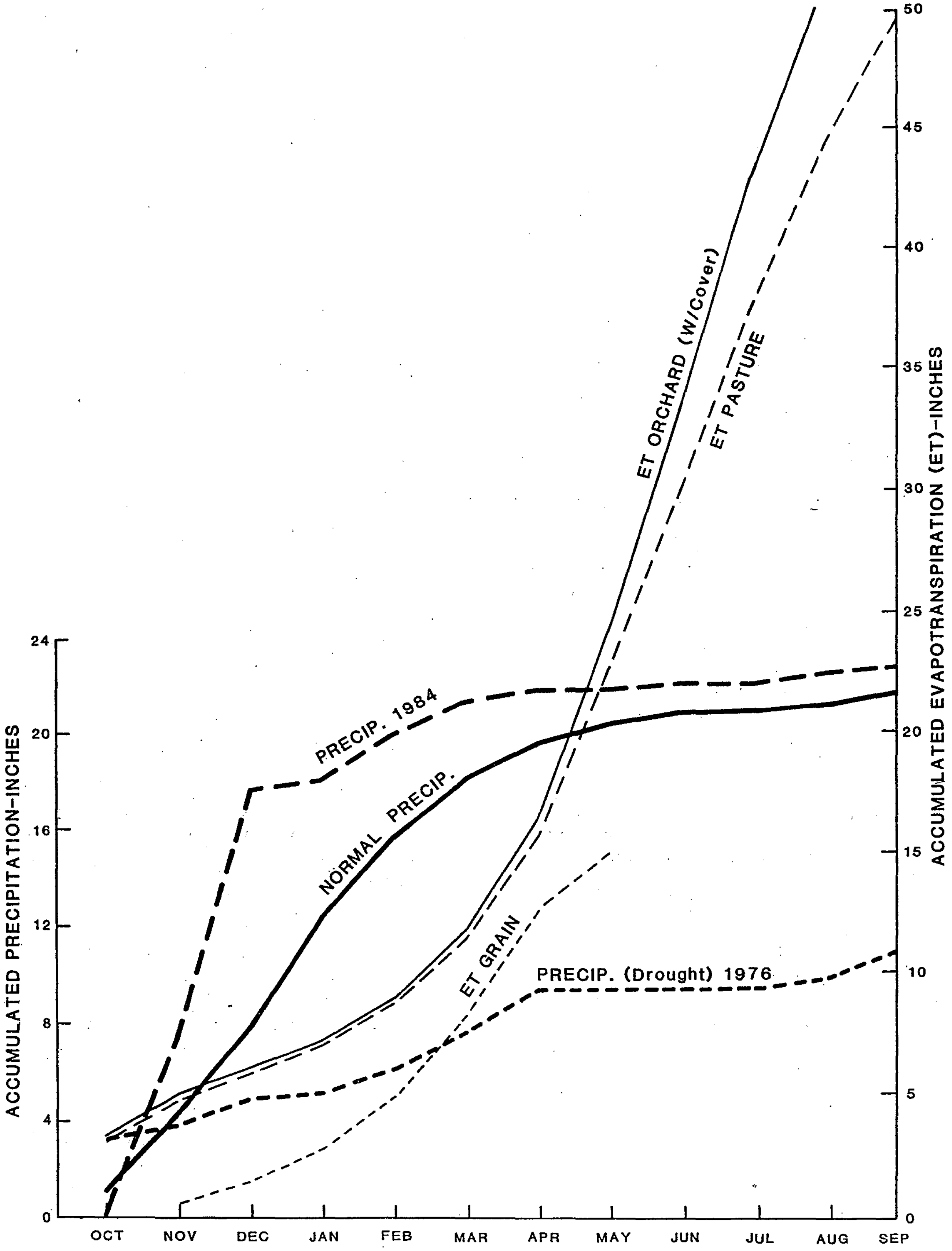


FIGURE 1. EFFECT OF PRECIPITATION DISTRIBUTION
ON CROP IRRIGATION REQUIREMENTS AT RED BLUFF

Figure 1 shows the effect of precipitation distribution on irrigation needs by orchards with a cover crop, pasture, and winter grain growing near Red Bluff (22 inches mean annual rainfall).

Figure 1 also shows that during the drought of 1976, grain (barley and wheat) required irrigation as early as January to prevent stress and to maintain growth. Without irrigation, the crop would have been desiccated by the end of February. As shown in Figure 1, for a normal year distribution of precipitation, the crop would not be stressed for moisture. Oddly, even though total precipitation during the 1984 water year (October 1983 through September 1984) was slightly greater than during a normal year, effective precipitation may have been significantly less than during a "normal" year. This was due to the large portion of total precipitation that fell as intense rains during November and December 1983. This intensity would tend to cause greater runoff than during a year of normal distribution. Therefore, soil profile storage of effective precipitation, for later crop use, would likely be low.

Also, Figure 1 shows that pasture irrigation during normal years begins about April 1. Drought years, on the other hand, require irrigation during winter months.

Most irrigated agriculture in California is located in the 500-mile-long great Central Valley, where mean annual rainfall varies from 5 inches near Bakersfield to 40 inches near Redding. Evaporative demand is nearly the same throughout the valley. Therefore, disregarding the influence of advection, evapotranspiration for any particular crop is nearly the same throughout the valley. During normal rainfall years, soil profile storage of precipitation significantly reduces the spring applied water requirement of crops in the north end. In the south end, precipitation near Bakersfield during normal years does not significantly contribute to crop-applied water requirements. As a matter of practicality, even wet years in the south end are equivalent to a drought elsewhere in terms of effective precipitation.

Measuring Applied Water

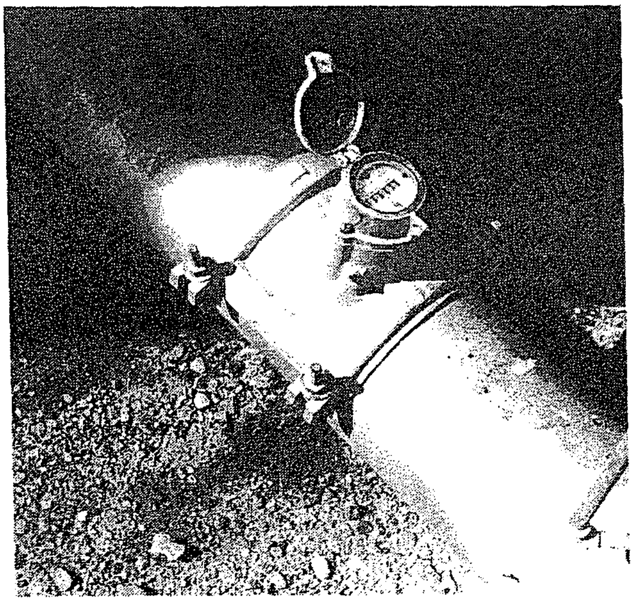
One of the most difficult and costly water data elements to acquire is that of crop-applied water. This is due to the large number of variables typically encountered and to the fact that only a relatively few farmers measure water applications. Further, because of problems with various methods of measurement not all the data is considered reliable. This section describes the various methods of measurement, highlighting some of the problems encountered.

Measuring Methods

Measuring irrigation water can be categorized into three methods:

1. Direct measurement method
2. Velocity-area method
3. Constriction of flow method

Direct Measurement. Small flows can be measured by timing the filling of a container of known volume. For



Inline water flow meter, propeller type

instance, if the dimensions of a farm reservoir are known, the drop in water level with time can be noted.

In most cases, the most accurate direct measurement of applied water is obtained with a properly installed and maintained in-pipe water meter. Typically, water meter manufacturers claim an accuracy of measuring within plus or minus 2 percent of actual flow. Most agricultural water meters for individual field use have a propeller-driven register that records accumulated flow in either gallons, cubic feet, or acre-feet. As an additional feature, some brands provide a rate-of-flow indicator that reads in gallons per minute. Appendix C presents criteria for properly installing and maintaining water meters and warns of situations that can produce inaccurate readings.

Velocity-Area Method: Several pitot-tube designs are in use for measuring instantaneous cross-section velocity flow in metal pipes. A specially fabricated stainless-steel tube containing minute openings upstream and downstream integrate the various velocities of flow across the pipe diameter into one reading. The pipe's internal area is used to determine rate of flow (e.g., gallons per minute or cubic feet per second). The problem with this method is that it usually represents only a one-point-in-time sampling. Some users of this type of flow device leave them permanently in place, thereby subjecting them to plugging by minute particles of sand and other debris. Erroneous readings could result.

Rate of flow may change for any one of several reasons. For example, there may be a change in head with time if the water is being supplied by a farm reservoir. Change in flow volume from ground water wells is usually caused by a lowering of the ground water level. This lowering can also be caused by well interference when closely spaced wells are operating simultaneously and their ground water drawdown zones overlap. Internal combustion engines usually have an adjustable throttle, which allows variation in engine rpm, and therefore variation in volume of pumpage is possible. A measuring device that continually measures and accumulates flow accounts for such variations.

Some electric utilities in California help minimize the waste of electric energy by performing free irrigation pump efficiency tests. These tests, which must be requested by the customer, determine, among other things, the rate of pumping at the time the test is conducted. This provides a basis for estimating the total amount of irrigation water applied. Corrective maintenance is recommended for inefficient pumping plants and, if performed, may significantly increase the volume of flow. If significant changes are made to a pumping plant a second pump test should be made to determine the new pumping rate.

Measuring flow in an open ditch is sometimes done by placing a small buoyant object, such as a twig or piece of straw, near the center of flow and timing its movement down a measured distance. The cross-sectional area of the ditch is then used to determine volume of flow in cubic feet per second. However, this is a rather imprecise method.

Several other relatively simple methods of measuring flow in open ditches or conveyances exist. The use of orifice plates of known size and the measurement of head above the opening are good for measuring flows in furrows. A velocity-head rod is only fairly accurate but inexpensive. It must be used where flows and water depths are not excessive. The rod is placed in the bottom of the channel with the pointed edge facing directly upstream, and a reading is taken. A second reading is obtained by orienting the pointed edge downstream and the blunt edge directly upstream. The difference in readings is used to determine velocity. The velocity is multiplied by the channel cross-sectional area to give volume in cubic feet per second.

Constriction Flow Devices. Simply stated, a constriction flow device channels water through a predetermined area and provides for direct or indirect measurement of water pressure (head). These devices can be either permanently or temporarily used with a piped or open channel system. They can be made of wood, metal, plastic, or concrete and are fabricated to meet predetermined specifications of constriction for use with existing tables to determine volume of flow. Depending on the device used, one or two easy measurements are required.

Sprinkler nozzles are a common constriction flow device, from which the volume of water applied can be is determined from nozzle orifice size, water pressure, sprinkler spacing, and length of operating time. Although application rates can be calculated from these design criteria, sprinkler systems are often inadequately maintained, resulting in different rates. Water applied typically exceeds designed rates primarily due to nozzle wear; other factors causing leaks may be worn and leaking sprinkler bearing gaskets, improperly seated or deteriorated rubber coupler gaskets, or breaks in the aluminum or plastic tubing. Other constriction flow devices are also used to measure flow in closed pipe systems.

Weirs, the second most commonly used on-farm, water-measuring device, measure flows in open channels. Weirs are notched barriers placed across an open channel. They come in assorted standardized shapes and sizes. All have flow tables available to provide speedy access to flow rating.

Volume and frequency of fluctuation of flow to be measured are primary concerns when determining the type of weir to be used. The water should be free of floating trash. In most instances, a graduated staff gage is mounted upstream of the weir for quick and easy reference. Where a more accurate accounting of total flow is needed, a water stage recorder provides a continuous record of any changes in water level, and therefore volume, passing through the weir. Without a water stage recorder, it can only be assumed that flows were constant and that the estimated amount of water applied during an irrigation was correct.

Data Collection and Analysis

The Department has a continuing program to collect and analyze unit applied water data. When irrigation district delivery measurement data are available, the records are analyzed to determine several critical factors of data suitability. For the measurement to be useful in deriving estimates of areawide average application rates, supplemental information is needed on (1) how the measurements were made, (2) the irrigation system, (3) whether there was no other source of irrigation, (4) the quality of crop management, (5) field size, (6) the crop, (7) whether there is irrigated crop land in the upwind vicinity of the field in question (to eliminate advective energy effects), and (8) the crop representativeness of the study area as a whole.

Often the measured well or canal supplies a network of fields containing more than one crop. Such data are of no value.

California has no legal requirements that on-farm applied water be measured. Therefore, in addition to canvassing suppliers of agricultural water and individual farmers to collect and evaluate what measurement data do exist, the Department has installed and operated several dozen in-line water meters in regions where no satisfactory applied-water measurement data are available.

Appendix H, "Average Measured Irrigation Deliveries in Selected Areas of California," summarizes the data assembled during the last decade.

Table 1. Estimated 1980 County Average Unit Applied Water[1]
(acre-feet per acre)

County	Grain	Rice[2]	Cotton	Sugar Beets	Corn	Other Field	Alfalfa	Pasture	Tomatoes	Other Truck	Almond Pistachio	Other Deciduous	Citrus Olive	Grapes
Alameda	0.7					2.4	4.0	4.3		2.6		3.5		2.1
Alpine								4.8						
Amador					2.7	2.2		5.3						3.0
Butte	1.1	7.5		4.0	3.1	2.8	4.8	5.7		2.1	2.6	3.7	2.2	3.4
Calaveras								4.9						
Colusa	0.9	8.5		4.0	3.1	3.1	5.8	6.6	3.6	2.2		3.7		3.3
Contra Costa	1.2			4.0	3.2	2.4	4.0	5.0	2.9	2.7		3.7		2.9
Del Norte								1.8		1.0				
El Dorado								4.3				1.9		
Fresno	1.3	6.3	3.7	3.8	3.6	2.9	4.3	6.0	3.3	1.9	2.7	3.7	2.6	3.4
Glenn	0.9	8.5		4.0	3.1	3.1	5.8	6.6	3.6	2.2	2.6	3.7	2.8	3.3
Humboldt							1.6	1.8		1.0				
Imperial	3.6					4.8	6.5	7.9		2.3			5.5	
Inyo							7.2	7.2						
Kern	2.2	6.7	3.7	3.9	3.1	2.7	5.1	7.0	3.3	2.0	3.1	4.3	3.0	3.1
Kings	1.4	6.7	3.7	3.8	3.5	3.1	4.3	6.2	3.3	1.8	2.9	4.3	2.9	3.8
Lake							3.7	4.2				2.3		2.3
Lassen	1.9				2.7		3.2	3.5						
Los Angeles	0.5					3.7	6.5	7.2		2.5		4.0		
Madera	1.2		3.8	3.7	3.5	2.4	5.1	6.3	3.3	2.1	2.8	3.9	2.8	3.7
Marin														
Mariposa								4.0						
Mendocino								3.2				2.0		0.9
Merced	1.1	6.7	3.7	3.7	3.5	2.6	4.8	6.1	3.2	2.1	2.6	3.9	3.0	3.5
Modoc	2.0					3.0	3.3	4.1		3.0				
Mono							5.9	4.9[3]						
Monterey				3.5		2.2	3.9	3.5	2.4	2.1		2.0		1.8
Napa								4.0						1.2
Nevada								4.2				1.8		
Orange						3.1				2.5			2.4	
Placer	1.4	7.4				2.4		4.8				4.8		
Plumas	0.5						3.0	3.5						
Riverside[4]	0.4-					3.2-	4.4-	5.3-		2.2-		3.2-	2.3-	2.1-
	2.8					3.8	6.5	9.2		3.0		5.6	5.8	4.7
Sacramento	1.2	7.2		3.8	3.2	1.0	4.2	5.0	3.1	2.0		3.7		2.8
San Benito				2.1		1.5	3.2	3.4	2.3	2.5		1.5		1.3
San Bernardino	0.5					3.4	4.9	5.6		2.5		3.5	2.6	2.3
San Diego	0.5					2.3	3.7	4.2		2.5		2.9	2.1	1.7
San Francisco														
San Joaquin	1.1	6.7		3.8	3.2	2.2	4.1	4.8	3.0	2.5	2.4	3.0		2.7
San Luis Obispo	0.6					2.1	3.7	3.8	1.8			3.2	2.0	1.3
San Mateo										2.5				
Santa Barbara	0.6					2.2	3.4	3.5		2.3		2.7	2.0	1.3
Santa Clara	0.3					2.5		3.7		2.5		2.7		1.2
Santa Cruz								2.7		1.6		1.0		
Shasta	1.3					3.0	3.5	6.2		2.3				
Sierra							3.0	3.5						
Siskiyou	1.9					2.1	3.2	3.3		2.9				
Solano	1.3			3.8	3.2	1.6	4.3	5.2	3.1	2.1		3.1		1.7
Sonoma						2.0		3.4				1.8		1.0
Stanislaus	1.1	6.7		3.8	3.6	2.3	4.9	6.0	3.3	2.2	2.7	4.0	2.4	3.5
Sutter	0.9	7.8		3.9	3.2	3.0	4.5	5.6	3.5	2.1	2.6	3.7		
Tehama	0.9	6.8		4.0		2.8	5.8	6.6		2.2	2.6	3.7	2.8	3.4
Trinity								3.0						
Tulare	1.4	6.7	3.8	3.7	3.5	2.7	5.1	6.5	2.9	2.1	2.7	4.2	2.8	3.8
Tuolumne								4.0						
Ventura	0.5					2.6	4.4	5.4		2.5		3.5	2.5	1.7
Yolo	1.3	7.4		3.8	3.2	2.0	4.3	5.2	3.1	2.4		3.7		2.9
Yuba	1.4	7.4			3.2	2.4	4.4	5.0		2.0		3.7		2.9

[1] Based on Department of Water Resources Bulletin 160-83, "The California Water Plan - Projected Use and Available Water Supplies to 2010," December 1983.

[2] See text for comments on recent trends of significant decreases in values for some areas.

[3] Includes areas with less than full season supply.

[4] Upper value is for coastal drainage portion of county; lower value is for the desert portion.

Estimated Average Unit Applied Water by County

The Department prepares estimates of area-wide average unit applied water by crop. These estimates are necessary for the many Department studies and activities and are prepared for a variety of geographic areas. These estimates are partially based on the average measured irrigation deliveries summarized in Appendix H. Other considerations are observations of the variations in irrigation systems and practices and the soil, crop and water-supply factors that influence these practices within each planning area.

For the Department's Bulletin 160-83, "The California Water Plan - Projected Use and Available Water Supplies to 2010," estimates of year 1980 agricultural applied water were reported for each of the 12 hydrologic study areas into which the State is divided. Those estimates were developed from crop acreage data and estimated crop unit applied water values in smaller analysis areas called planning subareas (PSAs) and detailed analysis units (DAUs) (see Figure H-1). PSAs are made up of DAUs, just as hydrologic study areas are made up of PSAs. The boundaries of all three areas are determined principally by hydrologic features, specifically the boundaries of stream drainage basins and ground water basins. However, PSA and DAU boundaries within large valley floor areas are commonly delineated to include the service areas of one or more water agencies, such as irrigation districts. In the major agricultural areas, a DAU typically covers 100,000 to 300,000 acres. Subsequent to the publication of Bulletin 160-83, some of the data and developed information were reorganized and summarized by county areas. This was done to assist local area studies. Table 1 presents the resulting crop unit applied values for each county having a significant amount of irrigated area. They are weighted average values calculated from each county's total crop acreage and calculated applied water.

Some caution should be exercised in using these values. They are most valid for studies covering complete county areas. For a study of only part of a county, however, an assessment should be made of how well overall irrigation practices in that portion conform to the county average. In some cases, climate, soil, water availability, etc., differ greatly from one portion of a county to another. This could, and often does, result in significant differences in irrigation-water application rates.

It may be appropriate to contact the Department of Water Resources to determine if more representative unit values have been developed for a study area wherever this occurs. Also, in some cases, there may have been significant changes in irrigation efficiency since the work done for Bulletin 160-83. The Department of Water Resources may have information on this. One example is rice, where recent efforts to control herbicide residues and the planting of new short-statured, short-season varieties have resulted in substantially less applied water.

CHAPTER III. CROP EVAPOTRANSPIRATION

Introduction

Bulletin 113-3 presented crop evapotranspiration (ET) measurements taken during 1957 through 1972. This bulletin presents certain ET measurements obtained since that time. Bulletin 113-3 also presented estimates of crop ET for various geographic subdivisions of the State. An update of some of the information used in deriving such estimates is also presented in this bulletin.

Measurements of crop ET are necessary for water use studies made by DWR and other agencies. ET measurements are used in hydrology studies to estimate present and future agricultural water use, in studies of sewage-effluent land disposal and evaporation from sewage ponds and proposed reservoirs, and in irrigation scheduling models, to cite a few examples.

Chapter III describes the various methods of obtaining crop ET measurements through direct determination of soil-moisture loss and by empirical means based on several climatic factors. The ET measurements reported here were taken at Davis, Brawley, and Tulelake from lysimeters. ET measurements from Wasco 8 SW (25 miles northwest of Bakersfield) were obtained by neutron probe.

Historic Review

DWR's ET studies began in 1954, when data from USWB Standard Class "A" evaporation pans were determined to provide the most practical approach to estimating ET statewide. Pan evaporation represents the integrated effects of solar radiation, wind, air temperature, and humidity in just one reading. The pan evaporation rate for an area is referred to as the evaporative demand. Detailed research has shown that monthly evaporative demand measurements provide a good index to estimating evapotranspiration.

Class "A" pans were initially sited primarily throughout northeastern California's intermountain region and in the Central Valley (Redding to Bakersfield). The purpose was to determine the variability of evaporative demand within each region. After a period of several years, average monthly evaporative demand was used as a primary reference for estimating crop evapotranspiration.

Many Class "A" pans were installed in flood-irrigated meadow or mixed-grass pastures. Lysimeter tanks for obtaining measurements of crop ET were also installed but only at a few key lysimeter-pan reference locations. Most pan and tank installations were made by DWR. Several tanks were installed by other agencies.

DWR had lysimeters at Coleville (Mono County), Alturas (Modoc County), Lookout (Lassen County), Glenburn and Pittville (Shasta County), Thornton (San Joaquin County), Arvin (Kern County), Guadalupe and San Luis Obispo (San Luis Obispo County), and Soledad (Monterey County). Lysimeters were installed and operated by the University of California at both Davis (Yolo County) and Tulelake (Modoc County). Other lysimeters were operated by the USDA-ARS at Lompoc (Santa Barbara County) and Brawley (Imperial County). One or more lysimeters were operated at each site.

Methods of Determining Evapotranspiration

Evapotranspitation can be determined by direct measurement or estimated by empirical methods. Direct measurement generally produces more accurate ET values than do empirical methods, but direct measurement equipment must be properly designed, sited, and operated. The best lysimeters can very accurately measure ET to within 0.001 inch of the actual daily rate and give good accuracy for periods as brief as one-half hour.

The best empirical methods can produce monthly estimates of ET within about 95 percent or more of the actual amount. ET accuracy of most empirical methods diminishes as the time period shortens, e.g., monthly, weekly, daily, and down to hourly. The following discussion is intended to highlight the methods and problems associated with the measurement and estimation of crop ET. The information can be helpful in the evaulation of measured and estimated ET.

Direct Measurement Methods

Direct measurement of ET using lysimeters is a relatively expensive procedure because of the high cost of equipment and installation and labor intensiveness to maintain cultural practices. Weighing lysimeters are adequate for most research. Some are constructed to use strain gages for obtaining weight measurements. Another type is mounted on a rubber pillow filled with water, which produces a reading in a site tube. Still another type has air chambers and is capable of floating within a closed water system; a variable water stage recorder may be used to produce a continuous record of weight loss due to ET. Weighing and floating lysimeters are generally more accurate than inflow-outflow lysimeters. In addition to lysimeters, there are other methods for direct monitoring of soil moisture depletion, e.g., the use of neutron probes.

Weighing and Floating Lysimeters. The University of California, Davis, operates two large and very accurate lysimeters. The Davis lysimeter tank designs include (1) a 20-foot diameter by 3-foot-deep, direct weighing type supported on a scale (2) a tank measuring 20 feet by 3.2 feet deep that floats in water, and (3) a less sensitive tank measuring 6 feet by 8 feet by 4 feet deep supported by a rubber pillow filled with water. A lysimeter operated by the USDA Agricultural Research Service in Brawley measures 10 feet by 10 feet by 5 feet deep and is supported on a scale; scale accuracy is considered good. The Tulelake lysimeter measured 5 feet by 6 feet by 4 feet deep and was supported by a rubber pillow filled with a water-antifreeze solution; again, lysimeter accuracy was considered to have been good.

Inflow-Outflow Lysimeters. The simplest lysimeter can be a 1-gallon can containing soil and a plant. Water added and any drainage water must be measured or weighed. The container and plant can be weighed periodically (daily, etc.) to determine evapotranspiration; weight gain due to the uptake of CO_2 by the plant is usually considered to be insignificant and is disregarded. A lysimeter of this size is considered to have poor accuracy for most ET research.

Another type of inflow-outflow lysimeter has water continually flowing into it at a slow rate, from a clock-operated dropping orifice mounted on a supply tank of known dimensions. Excess water within the lysimeter tank is drained into a sump of known dimensions. Inflow and outflow are continually measured volumetrically, using variable-stage water recorders on the supply and sump water tanks. The difference between these two readings, plus precipitation and change in lysimeter water storage, is evapotranspiration.

Lysimeter Siting and Operation. Lysimeter siting within a field is as crucial as siting for agroclimatic stations. For example, relatively warm dry air advected from adjoining fields will result in excessive measured ET rates. The ET rate will therefore be nonrepresentative of average ET occurring in a large irrigated field. Field border effects that may occur are summarized in Appendix D.

Additional problems concerning lysimeter design and cropping may exist. Primary among these is the rim effect. The rim effect of a lysimeter can be caused by four things: (1) the air space between the inner and outer lysimeter tanks; (2) the exposed lysimeter tank metal; (3) poor or atypical crop stand; or (4) atypical soil moisture within the lysimeter. The heat contained in air can move into the open space between the lysimeter tank and the soil retainer tank and warm the lysimeter tank and soil. Likewise, sunlight striking the lysimeter tank metal causes heat to be conducted down through the metal and outward into the lysimeter soil. If the lysimeter soil is warmer than the field soil, lysimeter ET rates may not be typical of field ET rates.

Differences in crop cover and soil moisture within the lysimeter and in the surrounding field can be significant. Ideally, the cropped lysimeter is totally hidden from view and the lysimeter crop is identical in appearance and ground cover to the cropped field. Hand-watered lysimeters pose a continual problem for operators. Even if the lysimeter soil moisture is high, the field soil moisture may become low and field ET rate reduced; therefore, lysimeter ET rates may become elevated due to the reduced surrounding field humidity and elevated air temperatures. However, if the lysimeter soil moisture is low compared to field soil moisture, measured ET rates may be low in comparison to the rate occurring within the cropped field.

In most cases, the lysimeter tank perimeter does not represent the effective tank area. This is because even a low-growing crop such as grass usually grows beyond the perimeter of the lysimeter. This means that ET is occurring from a leaf surface area exceeding the area of the lysimeter tank soil. Likewise, it is possible for field-rooted plant parts to encroach onto the lysimeter surface, thereby lowering the lysimeter effective area. Those conditions must be considered when the data are interpreted.

Neutron Probe. A neutron probe can be a cost-effective, accurate, direct-measurement instrument, once the access tubes have been installed. Access tube depth is typically only 3 to 4 feet for scheduling irrigations for deep-rooted crops. But, for ET research studies on deep-rooted crops, tubes extending to 20 feet deep are sometimes needed to track irrigation water and the extraction of all soil moisture by the crop. If water from overirrigation percolates beyond the depth of the tubes or enters a water table, this quantity may be "lost" for measurement purposes. Conversely when a water table contributes water to a crop, it is impossible to determine accurately the crop ET rate.

Some of the ET measurements reported here were obtained with a neutron probe. Generally, to obtain accurate field measurements requires that (1) the probe be calibrated and (2) the access tubes are properly installed and deep enough to track quantitatively the movement of all irrigation and precipitation water added to the soil. Likewise, tube depth ideally should allow the monitoring of all moisture extraction by the crop. Ideally, neutron probe tubes should be adequately replicated so that the findings will be statistically significant. Neutron probe measurements obtained from the Wasco 8SW site (reported in Appendix J) meet these criteria.

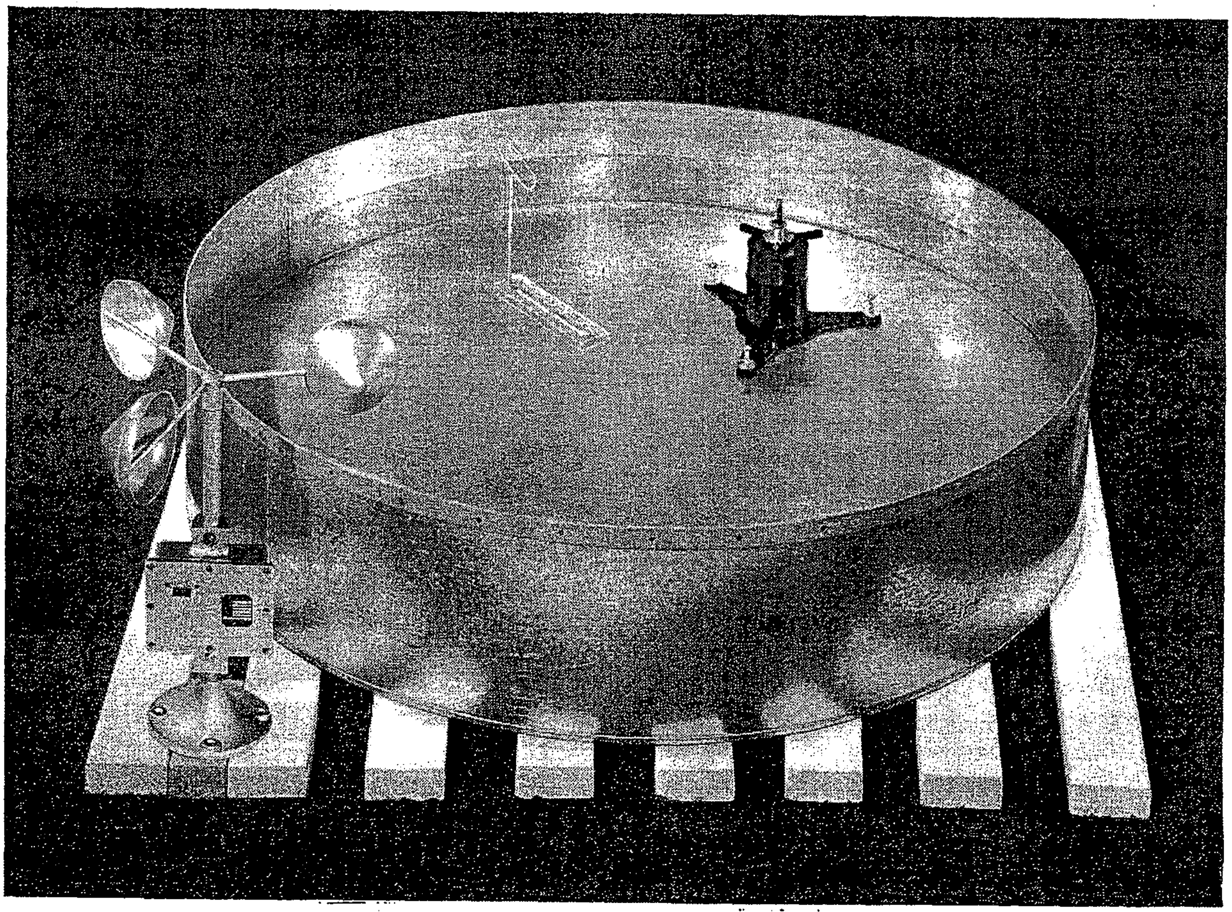
Other Methods. Several other less accurate devices for direct measurement of soil moisture are available. Some are suitable for making quantitative estimates of soil-moisture change within the plant root zone and for scheduling irrigations; others are best suited for scheduling irrigations only. The main devices are (1) tensiometers, (2) electrical blocks, (3) soil tubes, probes, and augers, (4) pressure bombs, (5) porimeters, (6) infrared guns, and (7) carbide soil-moisture testers.

Empirical Methods-Evaporimeters

Evaporation from evaporimeters, such as a Class "A" pan or Livingston black and white atmometers, provides a good basis for estimates of monthly ET.

Standard Class "A" Pan. Class "A" evaporation pans are the most commonly used evaporimeters in California and elsewhere. More data have been gathered and more is known regarding the application of Class "A" pan (Ep) data than is known about data from any other evaporimeter type.

To qualify as a standard Class "A" pan installation (agroclimatic station), the pan must be constructed of 22-gauge galvanized steel or monel metal. The circular pan measurements must be 10 inches deep and 4 feet in diameter. The pan must be operated on an open wooden platform constructed with 2-inch by 4-inch timbers, which raises the pan bottom 6 inches above the surrounding ground surface. Although dryland environments are sometimes resorted to by necessity, DWR prefers well-managed,



U. S. Weather Bureau Standard Class "A" evaporation pan with anemometer, stillwell, and hook gauge for measuring water level.

flood-irrigated pastures with extensive fetch for its standardized Class "A" pan installations. This standardized environment generally allows ET/Ep ratios (coefficients) developed from measurements from numerous past studies of crop evapotranspiration and evaporative demand relationships to be applied anywhere within the State. Ratios allow quick conversion of Class "A" pan evaporation to estimated crop ET.

A standard Class "A" evaporation pan integrates the effects of incident solar radiation, wind, air temperature, and humidity into one parameter: evaporation. Although the process is much more complicated, plants and soil integrate these same climatological effects into evapotranspiration.

A standard Class "A" pan takes in energy from three sides: (1) from the top, direct absorption of solar energy with some conduction of heat from the air, (2) conduction of heat through the side walls, and (3) through the bottom. For these reasons, the rate of evaporation usually exceeds water use by most crops. However, due to low maintenance requirements and a reasonably consistent ratio of weekly or longer period crop ET to pan evaporation, standard Class "A" pans have been widely used with good results.

A variety of other pan installation designs has been used by various agencies over the years. Sometimes pans are sunken in the ground with the rim 2 to 3 inches above ground level. The principal disadvantages of such ground pans are that they cannot be easily checked for leaks, they may be more prone to leak, and trash and small insects can fall into them more easily.

An index to agroclimatic station location, environment, and instrumentation in California is presented in Appendix F. Monthly pan evaporation data from these 24 agroclimatic stations are presented in Appendix G.

Livingston Atmometers. Technically, the term "atmometer" is any instrument used for measuring evaporative demand. Livingston atmometers are separate black and white porous ceramic spheres that are filled with distilled water; they are most often operated in black and white pairs. The black spheres absorb nearly all of the incoming solar radiation (>90%) and evaporate at a rate exceeding that from white spheres, which reflect nearly all of the incident solar radiation (>90%). Evaporation from Livingston atmometers correlates well with crop evapotranspiration and evaporation from a standard Class "A" pan.

Atmometer height above the ground has been demonstrated to have a significant effect upon evaporation rate from a single sphere, due to wind velocity differences within short vertical distances. However, black minus white bulb evaporation is little affected. Also of significance, atmometers require a calibration check at least twice each season due to the accumulation of dust and bird droppings. And, they are subject to breakage during freezing weather.

One-Gallon Can. Insulated, galvanized, one-gallon food cans with automatic feeding water supply bags have been developed by DWR for use in transect evaporative demand studies. These mini-pans require very little water for operation and therefore are ideal for ET studies conducted in remote regions where water hauling could be a problem for larger evaporimeters, such as a Class "A" pan. Construction and operation details are given in Appendix E.

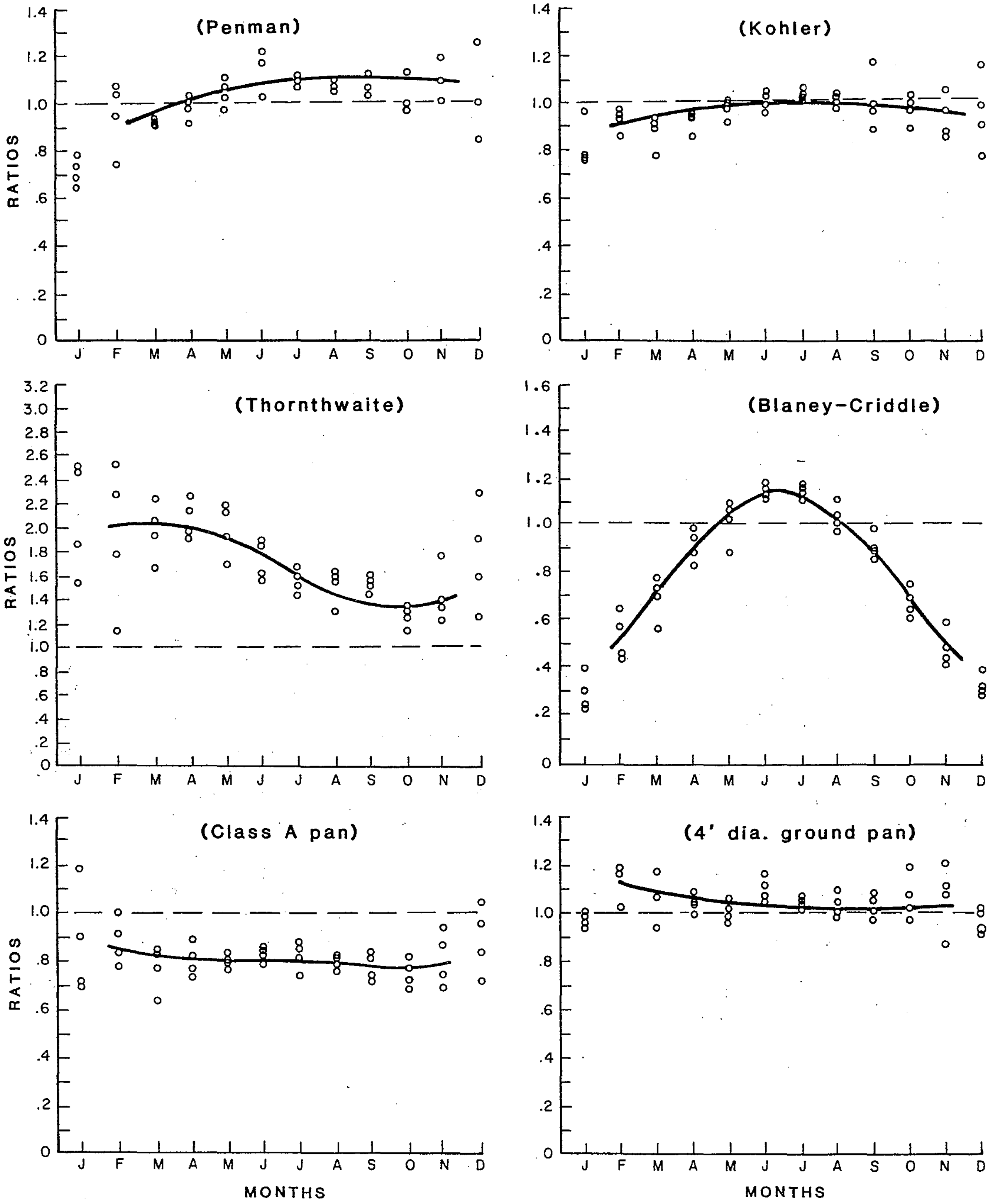
Class "A" Pan Ratios (Kp)

The monthly ET/Ep ratios (coefficients) presented in Bulletin 113-3 are now called Kp ratios. An example of the nomenclature sequence follows:

$$\frac{\text{Measured Crop Evapotranspiration}}{\text{Measured Pan Evaporation}} = \frac{ET}{Ep} = \frac{ET}{Epan} = Kpan = Kp$$

FIGURE 2

COMPARISON OF EMPIRICAL METHODS OF ESTIMATING ETo OF TURFGRASS AT DAVIS, CA[1]



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[1] Measured Turfgrass ETo represented by ratio 1.0 dashed line. Adapted from Pruitt, November 1963.

Pan Kp's are generally transferable to other locations in the State where ET measurements are not available but good-quality Class "A" pan data are; i.e., Ep x Kp = estimated crop evapotranspiration.

Kp ratios have been developed for estimating weekly ET for 14 crops grown within the Central Valley. The weekly ratios are presented in Table J-1. Most of the crops have multiple sets of ratios presented because of differences in leaf-out dates (e.g., deciduous orchards) and planting-harvest or senescence dates for annuals. Most of these weekly Kp ratios have been determined by Ferreres (1977) from monthly ET/Ep ratios presented in DWR Bulletin 113-3 (1975).

Strong, dry wind causes pan evaporation rates to greatly exceed crop evapotranspiration and therefore invalidate Kp ratios. For these strong, dry wind periods, pan evaporation rates must be reduced prior to applying the appropriate pan Kp ratios. Adjustment factors (as a function of wind and relative humidity) for evaporation data from standard Class "A" pans operated in irrigated pastures and turf grass are presented in Table J-2. Class "A" pan evaporation data from irrigated grass sites within the Central Valley seldom require an adjustment because of a combination of strong wind and dry air.

Empirical Methods-Equations

Well-known ET equations require the use of two to four climatological parameters. The accuracy of these equations on a monthly basis is often good to excellent. The parameters most often used are air temperature, humidity, wind, and solar radiation. Figure 2 compares monthly ratios for estimating ET(turfgrass) using the original modified Penman, Kohler, Thornwaite, and Blaney-Criddle equations, and evaporation data from two different types of evaporation pans. These comparisons should be helpful to anyone using these methods to estimate crop evapotranspiration.

Kohler Equation. Ratios for the Kohler lake evaporation equation were shown to have an accuracy comparable to the original modified Penman equation when used to estimate ET(turfgrass). However, the Kohler equation is not extensively used in California. It also uses four climatological parameters. Inputs of daily average air temperature and dew point, and total wind and solar radiation, are used with a nomograph to determine daily lake evaporation. As shown in Figure 2, the Kohler computed evaporation for a shallow lake is essentially equivalent to ET(turfgrass) during the months of highest ET.

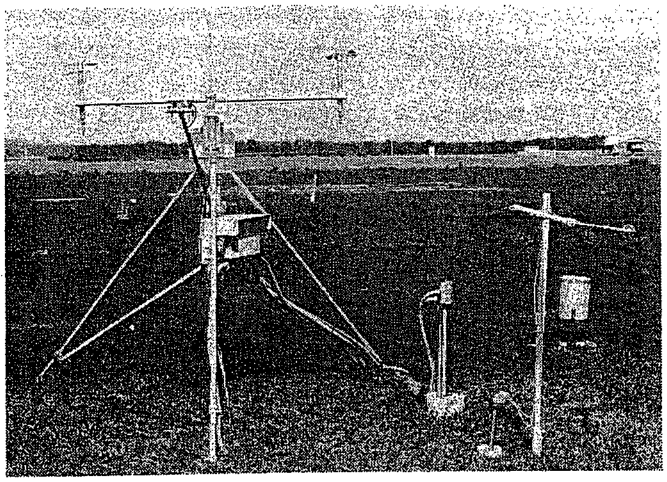
Blaney-Criddle Equation. The Blaney-Criddle equation was used extensively in California during the water resources studies of the 1950s. It was best used to estimate monthly ET in regions having measurements of air temperature only.

Penman Equation. The Figure 2 ratios for the Penman equation are based on a modification originally made by Penman to his equation for estimating evaporation from an open water surface. Penman's equation has since been modified and improved by others.

Probably the best known and most widely used equation in California for computing daily and hourly ET is a recent modification to the Penman equation by Pruitt. Pruitt's version of the original Penman modification was used by the University of California to develop the California Irrigation Management Information Service (CIMIS), an irrigation scheduling program developed for the Department of Water Resources. The University's modified Penman equation is used to determine daily turfgrass reference crop ET (ETo-CIMIS) from hourly computed values.

ETo-CIMIS Ratios (Kc)

The CIMIS-program computer calculates hourly ETo (ETo-CIMIS) from hourly averages of climatic data from 43 automated weather stations, most of which are in



California Irrigation Management Information Service (CIMIS) station gathers climatic data needed for calculating ET by the Penman equation

irrigated pastures or turfgrass environments. ETo values are adjusted to ET for other crops, using crop coefficients called Kc ratios.

Kc ratios are used to convert ETo-CIMIS to crop potential evapotranspiration. Kc ratios for Central Valley crops were computed by DWR and are presented in Table J-3. An example of the nomenclature sequence in the development of Kc ratios follows:

$$\frac{\text{Kp (crop)}}{\text{Kp (grass)}} = \text{Kcrop} = \text{Kc}$$

Kc ratios are used to adjust ETo-CIMIS to crop ET as follows:

$$\text{ETo} \times \text{Kc} = \text{ETcrop}$$

Recent ET Measurements

Bulletin 113-4 reports ET measurements taken from 1973 through 1983. The measurements are presented in Table J-4. ET measurements taken at the University of California Tulelake Field Station in Siskiyou County between 1966 and 1973 were not fully evaluated in time for inclusion in Bulletin 113-3; these measurements are summarized in Appendix J (Table J-4). Appendix J also contains three figures (J-1, 2, and 3) depicting the environment of the measurement sites.

Tulelake

ET measurements from the Tulelake Field Station were obtained from a lysimeter located within a test-plot environment. Figure J-1 shows the lysimeter fetch and test plot layout during 1973, a randomly selected year. Upwind fetch was not typical of commercial-size fields during portions of some years. However, daytime wind velocities typically averaged only 3 mph as measured at a height of 2 meters. Therefore, the ET data, although believed to be largely valid, should be used with these facts in mind.

Brawley

ET measurements from Brawley were obtained from a lysimeter located within an 8-acre field surrounded by research fields ranging in size from 4 to 8 acres. Figure J-2 identifies field plantings and fallow ground at the Irrigated Desert Research Station operated by the Agricultural Research Service during December 1978.

Davis

ET measurements from Davis were obtained from several lysimeter types located within an area generally devoted to moderately large test plots. Field plantings for 1973, a randomly selected year, are shown in Figure J-3.

Wasco

A 30-acre mature orchard of almonds near Wasco was used as a test plot for observations of soil moisture via neutron probe (DWR, 1979). The test plot trees were 11 years old in 1975, the first year of the 3-year study, and had a tree canopy ground cover of 85 percent. The orchard also contained plantings of younger almonds upwind of the mature trees, thus providing a total contiguous planting of 140 acres. The test plot contained 15 neutron probe access tubes;

soil moisture was observed at 1-foot increments to a depth of 12 feet or more.

Some of the findings were:

1. ET of almonds appears to be similar to that of other deciduous tree crops from leaf-out to late summer, at which time the common cultural practice is to allow the trees to go into moisture stress prior to harvesting.

2. Although soil moisture was available deep within the soil and roots were found to depths of 10 feet in augered soil samples, little use of deep moisture was evident until the trees had depleted the upper 4 feet to a point at or near the permanent wilting percentage.

Estimating Crop ET
for Irrigation Scheduling

In May 1974, DWR first began to publish estimates of crop ET in local newspapers for use by growers in scheduling irrigations. DWR field offices expanded this ET service throughout the Central Valley. These "current" estimates of past weekly total ET were computed with the use of evaporation data from Class "A" pans operated within excellent flood-irrigated pastures. The Kp conversion factors (pan coefficients) used to adjust pan evaporation to equivalent crop ET were taken from DWR Bulletin 113-3.

Estimates of daily crop ET tend to have relatively poor accuracy when computed on the basis of weekly Kp's and daily Ep. However, by the end of a week, crop ET totals have reasonably good accuracy, certainly good enough for irrigation scheduling. This is because variations in calculated daily crop ET tend to cancel out over a seven-day, or longer, period.

The most recent phase of technology transfer (i.e., providing daily estimates of crop ET to farmers and irrigation consultants) is being provided by the CIMIS program. Daily ETo-CIMIS data are generally available throughout California on the day following their occurrence.

ETo data users must have a computer terminal to obtain these data direct from the central computer. Although most irrigators do not have computer access to ETo-CIMIS, beginning in 1985 in some locations, daily ETo-CIMIS data replaced the crop ET estimates based on evaporation pan data formerly published in local newspapers.

APPENDIXES

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APPENDIX B

GLOSSARY OF TERMS

Advection. The movement of comparatively warm, dry air from nonirrigated areas into irrigated areas, which causes increased ET rates along the upwind margin of irrigated fields.

Agroclimatic. Climatic conditions within an area that influence, and that are influenced by, the agriculture of the area.

Agroclimatic Station (DWR). Usually, an instrumented 30-foot-square fenced plot of irrigated grass with a prescribed exposure, for measuring agroclimatic conditions.

Applied Water. See "Unit Applied Water."

Canopy. The cover of leaves and branches formed by the tops of plants.

Class "A" Pan Ratio (Kp). Kp = ET/EP; i.e., the numerical ratio of the depth of water in inches lost from a crop through evapotranspiration (ET) divided by pan evaporation (Ep).

Coarse-textured Crops. Crop characteristics (e.g., leaf aspect) and cultural practices (e.g., plant spacing) that cause increased ET due to (1) increased mixing of air within the canopy when there is wind, and (2) increased absorption and use of solar radiation.

Coefficient. See "Class 'A' Pan Ratio (Kp)" and "Crop Ratio (Kc)."

Crop Ratio (Kc). Kc = ET/ETo; i.e., the numeric ratio of the depth of water lost from a crop through evapotranspiration (ET), divided by the depth of water lost from grass (reference crop) evapotranspiration (ETo).

Effective Full Ground Cover. Percentage of ground covered by the crop when ET essentially reaches the maximum rate; generally about 60 to 80 percent cover, depending on the type of crop.

Effective Precipitation. The portion of precipitation that supplies crop evapotranspiration (ET). It includes precipitation stored in the soil before and during the growing season.

Effective Rooting Depth. The depth from which soil moisture is extracted; it is determined by the crop rooting characteristics (habits) and soil depth limitations.

ET. See "Evapotranspiration."

ETo. See "Reference Crop Evapotranspiration."

Evaporimeter. Any instrument used for direct measurements of evaporation.

Evapotranspiration (ET). The quantity (depth) of water transpired by plants, retained in plant tissue, and evaporated from adjacent soil surfaces during a specified time. As used here, evapotranspiration is synonymous with consumptive use.

Feel and Appearance Method (for estimating soil moisture). The procedure is to squeeze a sample of soil between the thumb and index finger and estimate the moisture content according to the descriptions in "Soil Moisture and Appearance Relationship Chart" in Transactions of the ASAE 3(1), pp. 31-32.

Fetch. Distance upwind to an abrupt change in site environment.

Fine-textured Crops. Crop characteristics (e.g., leaf aspect) and cultural practices (e.g., plant spacing) that, when compared to coarse-textured crops, do not cause significant increases in ET due to (1) increased mixing of air within the canopy when there is wind; and (2) increased absorbtion and use of solar radiation.

Ground Cover Percentage. The percentage of soil surface covered (or shaded at mid-day) by transpiring vegetation, when viewed from directly overhead.

Growing Season. A period during which crops experience growth and water use; normally considered to be planting-to-harvest for annual crops, leaf-out to leaf drop for deciduous perennials, and last spring frost to first fall frost for evergreens.

Irrigation Efficiency. Percentage of the total amount of water applied by irrigation that is retained within the root zone and that is available for crop ET.

Lysimeter. A container of known dimensions containing soil. Provision is made for the periodic or continuous determination of the amount of water added and removed, thereby enabling (1) measurement of evaporation only (no crop present) or (2) evapotranspiration from a crop.

Potential Evapotranspiration. See "Reference Crop Evapotranspiration (ETo)."

Reference Crop Evapotranspiration (ETo). The ET rate of healthy grass, completely covering the ground to a uniform height of 3 to 6 inches, and having an adequate supply of water and extensive fetch. ETo (CIMIS) is estimated by using the University of California modified Penman equation developed for use in the California Irrigation Management Information System.

Surface Irrigation. Irrigation in which the soil surface is used as a conduit, as in furrow and border irrigation, and as opposed to sprinkler, drip, or subirrigation.

Tailwater. Applied water that runs off the low end of a field.

Unit Applied Water. The quantity of water applied to a specific crop per unit area (sometimes expressed in inches of depth).

APPENDIX C

CRITERIA FOR INSTALLING AND MAINTAINING WATER METERS AND FOR EVALUATING EXISTING INSTALLATIONS

APPENDIX C. CRITERIA FOR INSTALLING AND MAINTAINING WATER METERS AND FOR EVALUATING EXISTING INSTALLATIONS[1]

Specific requirements for accurate measurements of water flow with an in-pipe water meter are:

1. the pipe must be full of water at the location of the meter;
2. the water must always flow in the same direction;
3. the flow volume and velocity past the meter must be within the manufacturer's recommended range; and
4. a meter should not be installed close to elbows, valves, or other fittings.

As a general rule, a straight section equal to five to eight pipe diameters in length, without fittings, leading to the meter will help avoid turbulence. In some brands, valves or fittings may be located as close as one pipe diameter downstream of the meter.

A meter can be mounted in a horizontal, vertical, or slanting position on the top, side, or bottom in either a pressure or suction position. It can be mounted on an existing pipe or on a 30-inch length of steel tubing, which is available from manufacturers with factory-installed straightening veins and an opening for mounting the meter. The installer must make certain that (1) the propeller points upstream into the flow of water and (2) the straightening vanes are installed upstream of the meter. It should be noted that straightening vanes are not a cure-all for poor site conditions. Rather, they stabilize twisting flows, but may not be necessary or even desirable when a straight section exceeding eight pipe diameters is available.

Sometimes a good site for installing a meter cannot be found. In some cases, gear-drive meters can be modified to enable mounting on the open end of the steel discharge pipe protruding inside a low-profile concrete standpipe. Although meter readings are still considered accurate in such situations, the procedure should not be attempted if there is a chance that the meter may be submerged inside the standpipe.

Agricultural water meters are manufactured with two types of mechanisms: magnetic drive and gear drive. Some magnetic-drive meters have partially sealed factory-lubricated mechanisms. Some manufacturers recommend that the meter not be disassembled for lubrication since more harm than good could result. If the water being metered contains magnetic sand, these particles may accumulate around the magnetic mechanism and enter the unsealed propeller drive unit.

1/ The use of brand names is not an endorsement of the products mentioned.

Nonmagnetic gear-drive mechanisms require lubrication with a light-viscosity grease. Manufacturers recommend not overgreasing, but usually don't provide adequate instructions. Field experience has shown that a meter greased once a month during midseason will typically require 20 pumps from a hand-pressurized grease gun[1] to lubricate the propeller nose bearings adequately. Weekly greasings during periods of heavy use are desirable. Improper lubrication of gear-drive meters can result if high-viscosity (e.g., axle grease) is used; heavy grease can cause slowing of the propeller, which may allow significant quantities of unmetered water to pass. Lubriplate No. 630-AA grease, which DWR has used for 10 years, appears to be satisfactory.

A good rule of thumb for lubrication of 6- to 10-inch nonmagnetic Sparling water meters is to apply one pump from the grease gun for every acre-foot (325,856 gal. or 43,650 cu ft) of water passing through the meter since the last lubrication, but not to exceed 20 pumps. Monthly greasing of nonmagnetic Sparling meters used in good-quality water has resulted in a life of 6 years or more without disassembly and replacement of bearings.

Most manufacturers say that their meters will register within 2 percent of true flow when the meter is installed correctly and operated within the recommended flow range. Here are some recommended flow ranges for various meter (pipe) sizes:

Meter Size[2]	Manufacturer's Recommended Flow Range[3] (gpm)
4	60-400
6	100-900
8	120-1200
10	160-1600
12	200-2000
14	260-2500

Shown below are typical errors that can result from metering flows outside the manufacturer's recommended ranges:

8-in. Meter Accuracy[4]

	Flow range gpm	Accuracy %
	1,500	96
	1,300	97
(Manufacturer's recommended flow ranges)	1,200	98
	550	100
	160	100
	120	98
	80	97
	70	96
	60	94
	50	85
	40	0

Errors in flow measurement can also result when water is supplied from surface sources and mollusks are present. Mollusks attached to the meter sleeve alter the flow pattern past the propeller, thus inducing errors.

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[1] Standard steel utility lever grease gun with 2-1/2-inch-diameter barrel, using 14-1/2-ounce grease cartridge.

[2] Slight differences in pipe diameter are caused by differences in steel pipe wall thickness; e.g., boiler tubing, well casing, and standard pipe (schedules 40 and 80) are different; meter size is considered as pipe size.

[3] Values shown are for Sparling in-line, low-pressure (<100 psi) meters.

[4] Values shown are from the Hersey-Sparling Meter Co. chart, "Accuracy and Head Loss Curve for Sparling Meters," and are for in-line low-pressure (<100 psi) meters.

APPENDIX D

AGROCLIMATIC STATION SITING AND OPERATION

APPENDIX D. AGROCLIMATIC STATION SITING AND OPERATION

During the past 30 years, the Department of Water Resources has established and operated a network of stations for the purpose of defining local and statewide evaporative demand zones and crop evapotranspiration (ET). These stations, called agroclimatic stations, vary in complexity. A basic station has only a standard U.S. Weather Bureau Class "A" evaporation pan and rain gauge. Equipment at the more complex agroclimatic stations will measure many climatic parameters, such as solar radiation, air temperature and humidity, wind, pan evaporation (Ep), and rainfall. To ensure that the data from a series of stations are comparable, each station site must meet a rigid set of criteria, as discussed in the following paragraphs.

Station Siting

The preferred environment for agroclimatic station operation is an extensive irrigated grass area, never short of water, with an effective full green cover and a maximum grass height of about 6 inches. In most instances, agroclimatic stations in California are sited in irrigated grass pastures, although University and Federal research facilities sometimes use a lawnlike turf grass location. The Department prefers to maintain a site with a full green grass cover throughout the year, so that grass ET at and around the station will occur at the "potential" rate. Theoretically, then, if the sites are similar, differences in instrument readings between stations are actually measuring true climatic differences, not just differences attributable to the site.

Ideally, an agroclimatic station should be located in a large, well-managed irrigated pasture. The location of the pan downwind of the field border should be indicative of the region the data is to represent. For example, to represent the vast contiguous fields of the Central Valley, the pan should be sited more than 500 feet downwind of the field borders. Needless to say, it is often difficult to find an ideal site with the minimum upwind fetch.

The importance of meeting those criteria for siting an agroclimatic station cannot be overemphasized. A grass site exposed to full sun and wind is essential to the collection of reliable data. Although well-managed, full-cover irrigated grass areas are preferable, the lack of such sites sometimes prompts the use of dryland sites. The problem with the latter lies in adjusting the evaporation data to parallel the conditions in a fully irrigated environment.

Dryland vs. Irrigated Sites

As discussed in the preceding section, an irrigated pasture site will have a good soil moisture supply at all times and a full green cover to permit ET to occur at the maximum potential rate throughout the year. An evaporation pan in such an environment is continuously bathed by relatively cool moist air from the pasture. Although consistently greater than ET grass, pan evaporation rates generally parallel water use by the pasture. This is caused by exposure of the pan to the same climatic effects of sun, wind, air temperature, and humidity as the pasture.

During November through March, rainfall sometimes supplies enough moisture so that Ep measurements at a dryland site will be about the same as those in an irrigated pasture. By spring, however, the soil moisture is depleted, the vegetation becomes dry, and the air becomes increasingly drier and warmer. Concurrently, the pan evaporation rate will increase considerably above the rate from an irrigated station site in the same region.

In the northern Sacramento Valley the mean annual precipitation is 20 inches. Average Ep from a dryland site during July, normally the month of greatest evaporation, is 37 percent higher than evaporation from a nearby irrigated pasture. On an annual basis, Ep from a dryland site averages 31 percent higher than Ep from an irrigated pasture (see Table D-1).

In the southern San Joaquin Valley mean annual precipitation is 5 inches. Average Ep from a dryland site during July is 71 percent higher than Ep from a nearby irrigated pasture. On an annual basis, Ep from a dryland site here averages 59 percent higher than Ep from an irrigated pasture (see Table D-1).

Average annual Ep from irrigated pastures from Red Bluff to Bakersfield is almost identical. For example, annual Ep is only 5 percent more at Red Bluff (65 inches) than at Bakersfield (62 inches). Yet, due to a significant difference in mean annual rainfall, annual dryland station Ep is 15 percent greater near Bakersfield. Those comparisons help show the benefit of operating an evaporation pan within a relatively large, stable environment, such as a well-managed irrigated grass pasture.

Alfalfa Fields

Irrigated alfalfa fields are a poor location for an evaporation pan. Depending on location, an alfalfa field

Table D-1
Comparison of Evaporation from Class "A" Pans
in Drylands and Irrigated Pastures

Location	Northern Sacramento Valley			Southern San Joaquin Valley		
Mean annual precipitation	20 inches			5 inches		
Fnvironment	Dryland (in.)	Irrigated Pasture (in.)	Differ. %	Dryland (in.)	Irrigated Pasture (in.)	Differ. %
January	1.8	1.5	13	1.5	1.3	15
July	14.0	10.2	37	15.9	9.3	71
Annual	85.3	65.2	31	97.9	61.7	59

Black Butte Dam (dryland) and Gerber 1 SW (irrigated pasture).
Lost Hills (dryland) and Wasco 8 SW (irrigated pasture) in Kern County.

will receive from two to seven or more mowings each year. Each mowing changes a relatively cool, moist environment of tall, dense, lush vegetation to one with an almost barren soil and a relatively warm, dry environment. Evaporation rates from a pan operated in an alfalfa field increase suddenly and significantly after each mowing. The pan evaporation rates gradually decrease as the alfalfa plants regrow.

Pan evaporation will eventually drop to a rate normal for a grass site, but will continue to decrease significantly as the alfalfa reaches a maximum ET rate at an effective full cover. In addition, alfalfa ET (at full cover and soil moisture) exceeds grass ET by about 10 percent, thereby suppressing Ep rates due to the additional humidity of the air passing over the pan.

Agroclimatic Station Operation

An ideal agroclimatic station size is 30 feet square, which allows adequate spacing of instruments. The grass should be kept close-cropped (3 to 6 inches) by mowing. The pasture area adjacent to the station enclosure would ideally be kept grazed in order to keep the station from operating in a "hole" created by waist-high grasses, as is the case just prior to cutting for hay. Waist-high grass around the station enclosure may reduce pan evaporation up to 20 percent.

Agroclimatic stations must be fenced to keep out animals, including deer. Hogwire or wire-mesh fencing, with several strands of barbed wire placed above to produce a total fence height of about 5 feet, is adequate where deer or horses are not present. Several strands of barbed wire placed vertically on outside edges of station corner posts help discourage cattle from rubbing themselves and pushing the posts over.

To reduce station construction cost, it is often possible to establish a station in a field corner where cross-fencing exists (need to build only two more station sides), or alongside an existing fence (need to build three sides). Station access by pickup truck to deliver water can be a problem in irrigated fields, since too much vehicular traffic can cause soil compaction and crop damage.

Climatological Instruments

In most cases, climatological instruments have standardized operating and maintenance requirements as established by the U. S. Weather Bureau and instrument manufacturers. Some of these criteria appear in the USWB Observing Handbook No. 2 (1970) and in operating manuals published by various instrument manufacturers. When criteria are lacking, DWR test results and judgment are used to develop guideline criteria. The following sections discuss some of these guidelines and recommendations gathered through many years of agroclimatic station operation. In general, wind-sensitive climatological instruments used to estimate crop ET should have a minimum distance of 4 times the height of massive nearby upwind single obstructions (e.g., a tree) and 10 times if the obstructions are massive (e.g., an orchard).

Solar Radiation Recorder. Portable, spring-wound clock solar radiation recorders, called pyranographs (also called pyrheliometers) should be operated in the station at a convenient height for servicing, usually about waist high. However, the height of the instrument above the ground or grass cover is not critical. Under dryland conditions an ideal situation would be to have the pyranograph elevated to minimize the accumulation of dust on the glass dome. Pyranographs can be operated on rooftops or other suitable areas as long as the instrument is free from shading by power poles, trees, fence posts, or other objects.

The instrument should be level, with the observation window facing south. Regardless of what day the recorder is serviced, the 8-day paper chart should be started on the first day ("Monday" on the chart) that follows the joining of the two chart ends. Avoid having the pen pass over the metal clip which holds the chart ends against the drum, because the clip can cause loss of data. The glass dome should be cleaned with distilled water and cheesecloth. The chrome reflective strip cover can be cleaned with any good-quality glass cleaner.

Anemometer. The "totalizing" anemometer records total miles of wind passing over the station but not velocity. If, for example, wind velocity for a 24-hour period were a constant 10 mph, the anemometer would record a total 24-hour wind movement of 240 miles.

Wind measurements (for use in estimating crop ET) are usually made by a totalizing anemometer mounted at either 0.5 or 2.0 meters above ground. There is about 30 to 35 percent more wind at 2.0 meters than at 0.5 meters above ground.

Rain Gauges. Rain gauges are constructed in many styles, sizes, and materials. Standard U. S. Weather Bureau gauges have an 8-inch orifice and 20-inch capacity. They are constructed of copper, galvanized steel, or aluminum. The standard height above ground for an orifice is 1 meter. Upwind objects, such as trees, buildings, power poles, etc., should not be closer to the gauge orifice than the object is tall. That means that the angle between the

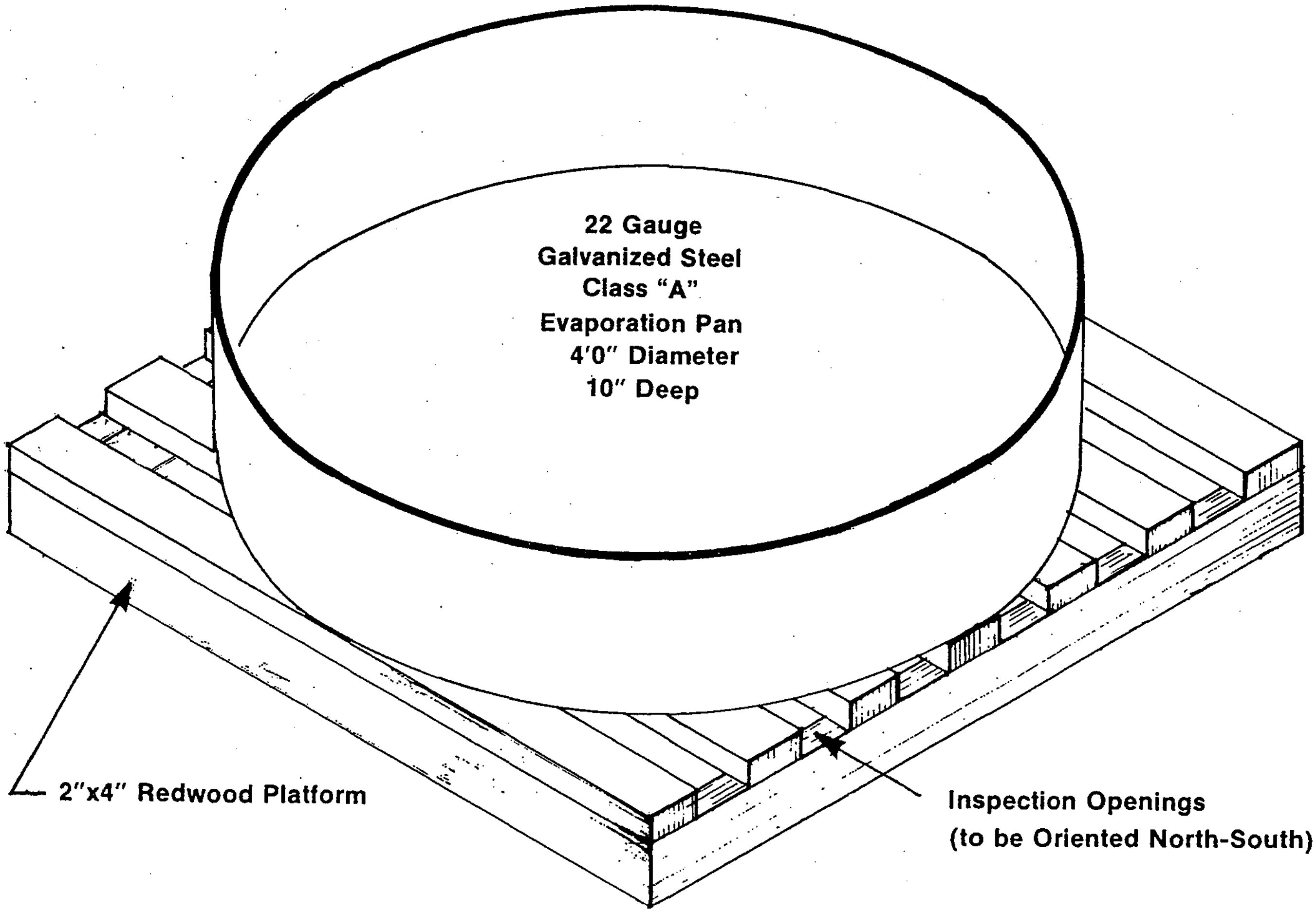


FIGURE D-1. CLASS "A" EVAPORATION PAN AND OPEN WOOD PLATFORM top of any object and the gauge orifice must not exceed 45 degrees. A much better criterion is not to have major objects closer than four times the height of the object.

Rain gauge height and orientation testing have been performed at some federal research facilities. A major finding was that the rain gauge catch is most accurate when the gauge is recessed in the ground and the orifice is at ground level (unfortunately, this is usually not a practical installation design). The findings for a standard gauge are that (1) the catch can be 50 percent low when very strong winds blow; and (2) most annual catch measurements may be low by as much as 20 percent due to the wind function.

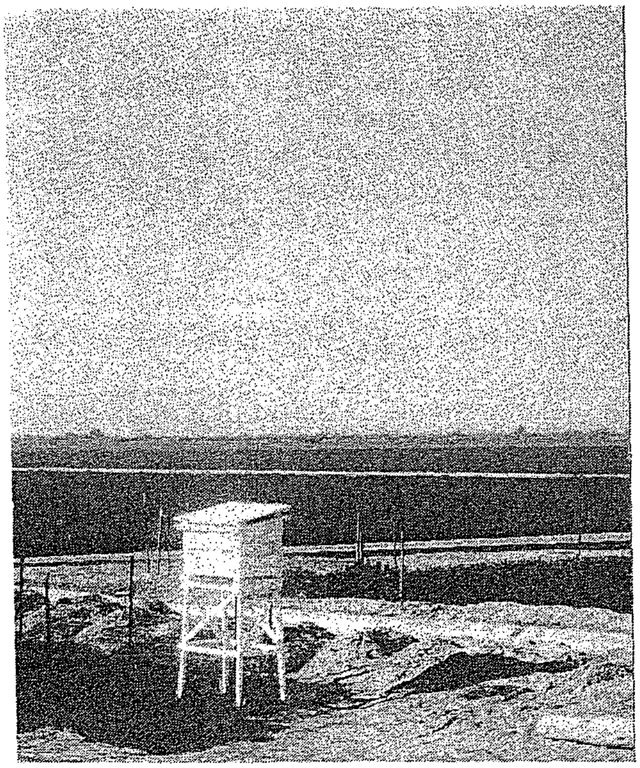
If the gauge is not read daily, a 0.02-inch layer of light viscosity transformer/insulating oil in the inner collector tube and 0.02 inch in the outer overflow collector will prevent evaporation. This is a very important procedure when an evaporation pan is operated for extended periods between servicing, because precipitation measurements are included in the computations of pan evaporation. For weekly winter gauge readings within a 12- to 20-inch annual precipitation zone, 3 ounces of antifreeze combined with a small quantity of light viscosity oil works well to prevent freeze damage to the gauge and makes reading and servicing possible. If oil or antifreeze is used in a rain gauge, the gauge should be the last instrument read and serviced prior to leaving the station in order to avoid contaminating the evaporation pan or other instruments.

Class "A" Evaporation Pan. A standard pan installation requires that the pan be mounted on a platform ("grille") made of 2-inch by 4-inch redwood or chemically treated lumber. The outer platform base is constructed with 2-inch by 4-inch lumber turned on edge. Construction details are shown in Figure D-1.

In the field, a north-south orientation allows best viewing of the pan bottom to check for leaks.

Birds drinking from the pan can be a problem in dryland environments. A screen cover should not be used because it can significantly reduce evaporation rates by shading the water from sun and wind. A hot wire around the outside pan rim and activated by an electric fence charger works very effectively to repel birds (see Appendix I). A pan located within an irrigated region is usually not significantly affected by birds. The 4-foot pan diameter requires a large volume of water to be removed to drop the water level by, for example, 0.1 inch.

The standard operating water level of a pan is within a 1-inch zone ranging between a 2- to 3-inch distance down from the pan rim (freeboard). Evaporation rates are too high if the pan freeboard water level is less than



Weather shelter
contains climatic recording instruments.

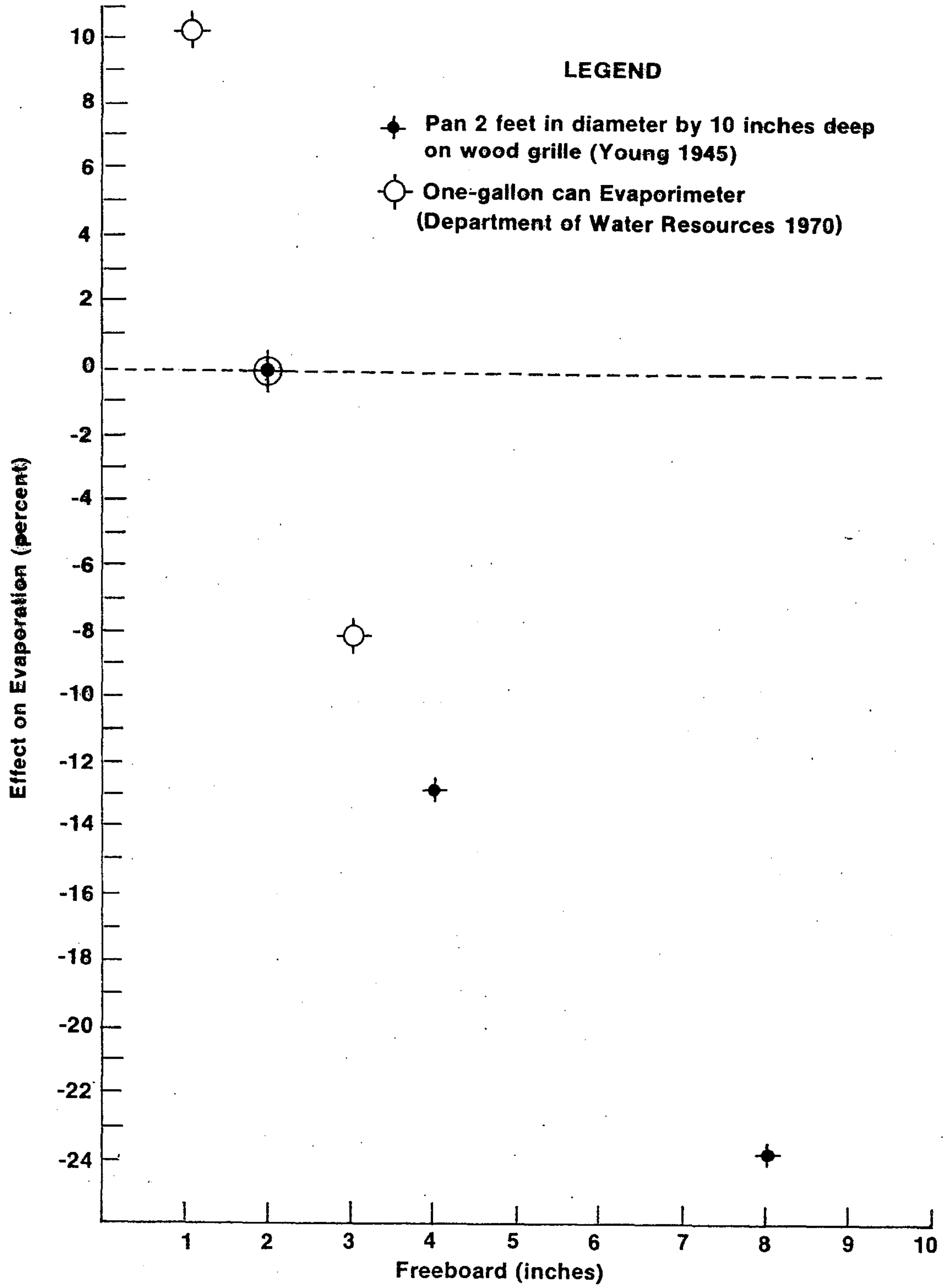


FIGURE D-2. EFFECT OF WATER LEVEL ON EVAPORATION RATE FROM EVAPORIMETERS

2.0 inches below the rim (Figure D-2). A freeboard of 2.0 inches is the standard reference level for a Class "A" pan. The Department has developed a water-supply tank and automatic float-valve system that will maintain any maximum predetermined pan freeboard.

During winter, an evaporation pan can be maintained with a 3-inch maximum freeboard. This allows precipitation to accumulate, while minimizing the potential for overflow. Experience has shown that a pan is likely to overflow due to strong winds when precipitation reduces the pan freeboard water level to 1.5 inches or less. In high rainfall areas, where equipment servicing is infrequent, an overflow tank can be used to store excess water siphoned from the pan. Interestingly, an evaporation pan makes a better rain gauge than does the standard rain gage because of its size and proximity to the ground, where wind velocities are reduced.

The buildup of algae on the pan bottom and walls reduces reflectivity. This causes the pan evaporation rates to increase by about 3 percent. The best algae control is to clean the pan twice a year with a fiber bristle brush. If water for the pan is difficult to obtain, household bleach does a reasonably good job of controlling algae; a disadvantage of using bleach is that the increased water salinity will decrease the evaporation rate. Salinity reduces the evaporation rate about 1 percent for each percentage of salt dissolved in the water (Young 1945). Pan color and reflectivity also affect the pan evaporation rate significantly. As shown in Table D-2, a galvanized metal Class "A" pan that has weathered (lost its shine) has a 6-percent higher rate of evaporation than a new, shiny pan.

Since hauling water during summer to meet pan evaporation becomes a major task, most DWR climatological stations use a supply-tank reservoir system to keep the pan supplied. The supply tank requires an external sight-tube water-level measuring device so that water losses can be determined. The supply tank system requires reading both the evaporation pan and tank water-level changes at each visit to the site. A water-cooler float valve mounted at the supply tank will maintain the maximum pan-water freeboard at any desired level.

Table D-2
Effect of Pan Color and Reflectivity
on Evaporation rate

Color of Class "A" Pan	Percentage of Evaporation from New Class "A" Pan
White (painted)	83
Aluminum (painted)	98
Galvavized (new)	100
Galvanized (weathered)	106

Source: Young, 1945.

How To Measure Pan Evaporation

Evaporation from a Class "A" pan can be measured with either a graduated cylinder especially designed for this use or a micrometer hook gauge. Each has advantages and disadvantages. Each device requires the use of a special stillwell, which is operated continuously inside the pan as the reference to changes in the pan water level.

<u>Graduated Cylinders</u>. The graduated cylinder requires use of a "fixed-point" stillwell. A fixed point is mounted permanently inside the stillwell as a water-level reference. To obtain a valid reading, the point must be wetted before water is added, and the pan water surface must be exactly level with the stillwell point, which means the stillwell holes must be kept free of algae growth.

A significant advantage of the fixed-point, graduated cylinder system is that the pan freeboard level must be returned to a standard height, usually 2 inches below the pan rim in order to obtain an evaporation reading. However, this can also be disadvantageous if winter rainfall is likely to cause the pan to overflow.

Another potential disadvantage of using a graduated cylinder is that the pan water may become contaminated with oil or other substance from a person's hands. For instance, when rainfall has exceeded evaporation, the water level will rise above the fixed point. To obtain an evaporation reading, the operator must submerge the cylinder in the pan water to remove the excess water; this is when the pan water may become contaminated. On the other hand, a definite advantage of the graduated cylinder is its simplicity of reading.

Micrometer Hook Gauge. The micrometer hook gauge is used to measure the depth of water added to or removed from a Class "A" pan. The use of a hook gauge requires a stillwell without a fixed point attached. The top of the stillwell becomes the reference point for all measurements. The hook gauge is placed on top of the stillwell, and the hook is adjusted downward until the point is wetted. The hook is then adjusted upward until the point on the hook is at the water surface. The vernier scale on the hook gauge is then read in inches, tenths, and hundredths.

Sometimes, the pan water level will become so low that the point cannot be lowered far enough to obtain a reading. When this happens, a bottom-of-the-hook reading can be obtained and corrected for the difference in distance from tip to bottom. Whereas pan evaporation rates are technically too low under such conditions, it may be preferable to a complete loss of data.

Stillwell openings must be kept clean, so that the water level within the stillwell is equalized with the water level in the pan. An old toothbrush works well for scrubbing algae growth from around the small stillwell openings.

Instrument Shelters. A louvered U. S. Weather Bureau "cotton region (instrument) shelter" box measures 30 inches wide, 20 inches deep, and 32 inches high. The shelters are large enough to house a thermograph or a hygrothermograph, along with separate maximum and minimum thermometers. Cotton region shelters are installed with the floor 4 feet above the ground, thereby placing the thermometers at a 66-inch height. The door should open to the north.

A smaller version of the cotton region shelter, measuring 14 inches deep, 20 inches high, and 19 inches wide, works well for a Six's type maximum-minimum thermometer. Because the shelter is quite small, it will not usually house a thermograph. The Six's thermometer inside the shelter should be installed so that its sensor is 66 inches above ground. As with the cotton-region shelter, the door should open to the north.

Stinging insects often will nest inside the recording instruments in the shelter. To prevent this, place a 2-inch-long section of "no-pest strip" inside the recording instrument.

Microclimatic Research

One of the problems in station siting is finding a location with a reasonably long upwind fetch of irrigated grass. The distance must be long enough to stablize the effect of dry, warm air received from an upwind dryland area.

Some microclimatic research has been conducted in California by the University of California, the California Department of Water Resources, and world-wide by various government agencies. The conclusions reached are varied, but generalizations can be made.

In summary, the climate-modifying

effects imposed by dry, nonirrigated areas on downwind, irrigated land are not extensive. Under strong winds (15 mph), they are significant up to the first 200 to 300 feet; they can be detected by evaporimeters for up to 500 to 700 feet. Conversely, the effects of lakes and irrigated land on dryland areas are much more extensive. The cooling and humidifying effects of a large water body, such as the Salton Sea, have been measured for a distance of nearly 2,000 feet into the desert. Some findings on microclimatic research follow.

Water Body Effects

Ribinsky Dam in Russia produced almost no perceptible change in the monthly average air temperature on shore, perhaps a few tenths of a degree; the average wind speed along the shore was doubled, but the effect was local.

The Salton Sea and Lake Mead scarcely changed the climate, even in the immediate vicinity, although both water bodies are located in an arid region. At a distance of 600 meters (1,968 feet) from the Salton Sea shoreline, the moisture content of the air is relatively unaffected.

Liakhov (1953) studied the influence of the Volga River on the microclimate of the adjoining desert. Climatological stations were established at a distance from 200 to 5,000 meters from the riverbank to determine the degree to which the river ameliorated a hot, desiccating wind. Modification of the humidity during daytime apparently was limited to within 500 meters (1,640 feet) of the river.

Irrigated Land Effects

Ohman and Pratt (1956) investigated the influence of the Puma irrigation project on desert humidity of Southwestern Arizona. The lateral extent of increased vapor pressure and decreased air temperature was limited to 30 meters (98 feet) or less into the desert.

DWR, Northern District, conducted tests in a dry, fallowed field located between two rice fields in the Sacramento Valley. The rice fields were located about 1,000 feet apart in a north-south orientation, which matches the two predominant directions of summer wind. The rice fields did modify evaporation to the center of the dry field or 500 feet. The effect might have been more extensive if the rice fields had been farther apart.

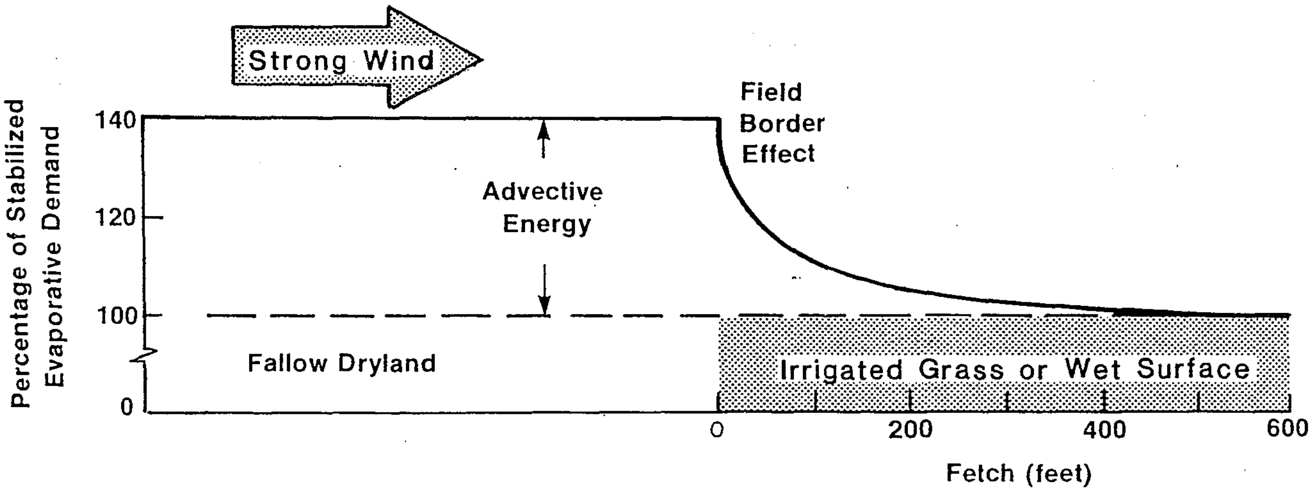


FIGURE D-3. SUMMERTIME ADVECTION EFFECT ON EVAPORATIVE DEMAND IN CALIFORNIA'S CENTRAL VALLEY

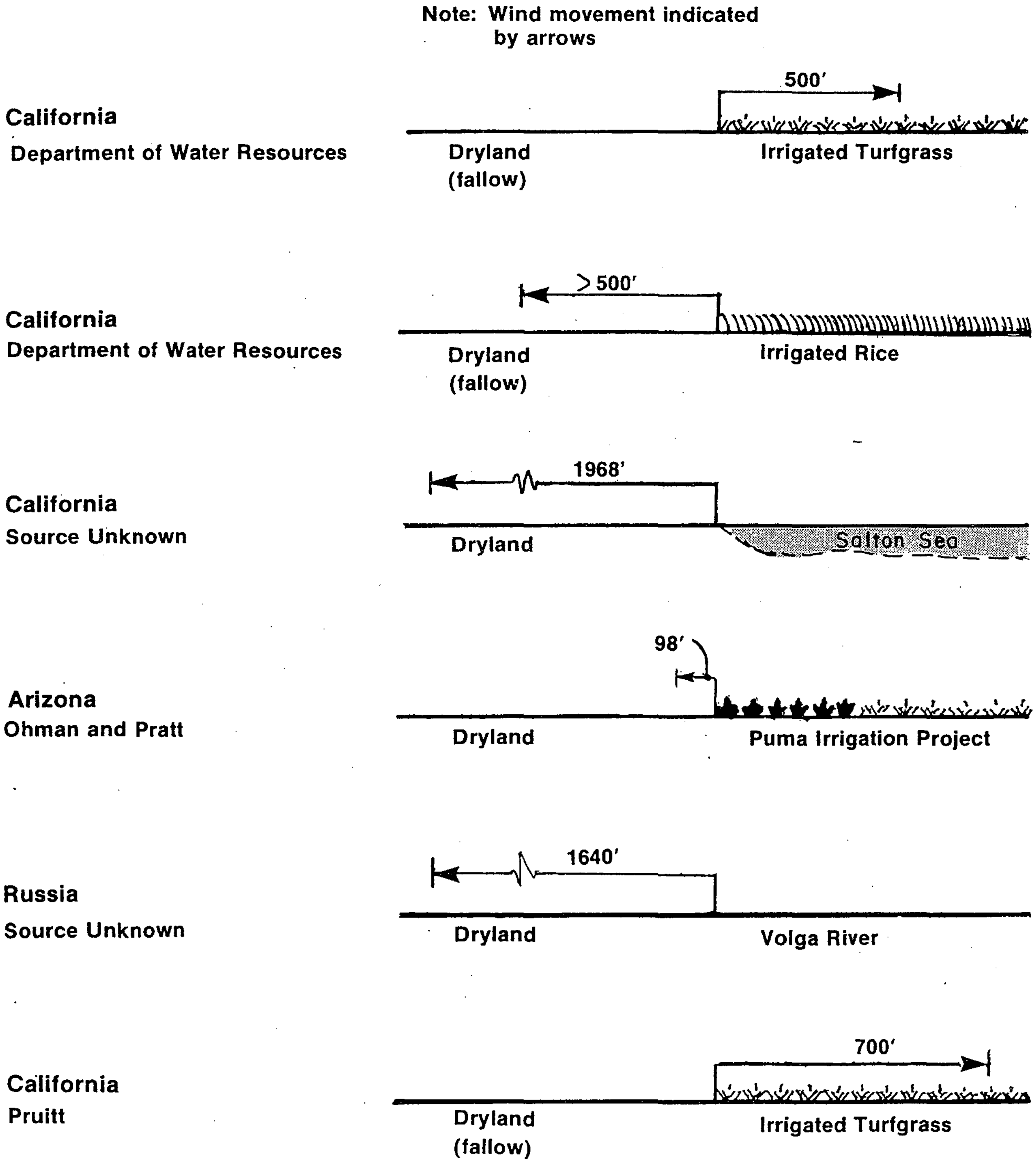


Figure D-4. MEASURED DOWNWIND DISTANCES AFFECTED BY WATER SURFACES, IRRIGATED LAND, AND FALLOWED DRYLAND

Dryland Effects

Another DWR advection test was conducted at U. C. Davis during 1967. The test demonstrated how a strong (15 mph) north wind can move warm, dry air into a field of healthy, full-cover, well-irrigated short turf grass. The warm, dry air originated from several hundred yards of dry, fallow field immediately upwind of the test area. Advection effects in the form of high evaporation rates from insulated 1-gallon cans were very significant up to the first 200 feet into the irrigated turf. The effects were detected for a total distance of 500 feet as shown in Figure D-3. For the test, insulated 1-gallon cans were extended a total distance of 860 feet into the field of irrigated, turf grass. DWR's findings are shown in Figure D-4. Recommended distances for locating Class "A" pans are shown in Figure D-5.

Data Forms. Forms recommended for the recording of agroclimatic station data are presented in Figures D-6 and D-7. The forms are similar except that Figure D-6 is designed for use where a graduated cylinder is used to determine evaporation loss from a Class "A" pan. Figure D-7 is for use with a micrometer hook gauge.

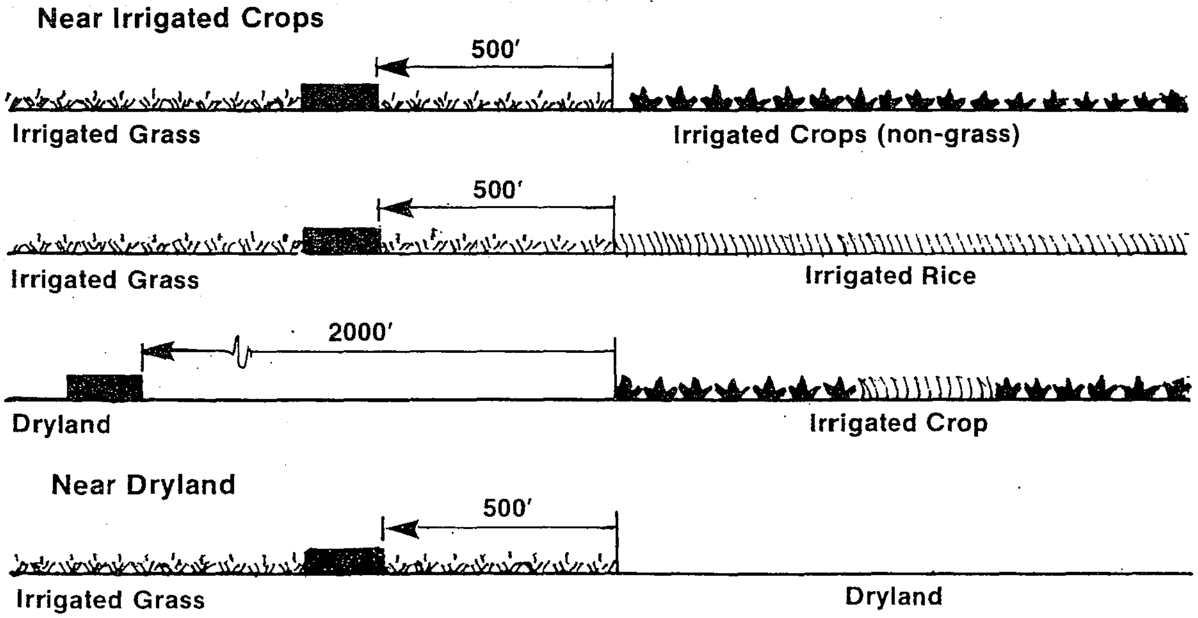


FIGURE D-5. RECOMMENDED MINIMUM DISTANCES FOR LOCATING A CLASS "A" EVAPORATION PAN DOWNWIND OF IRRIGATED AND NONIRRIGATED LAND

Figure D-6. PAN EVAPORATION RECORD AT FLOOD IRRIGATED STATION (FOR GRADUATED CYLINDER READINGS)

STATION NAME ______________ **YEAR** ______________

DATE	TIME	OBSERVER	AGENCY	GRADUATED CYLINDER READINGS (inches and hundredths) (mm)		("B") PPTN. (INCHES) (mm)	PAN EVAP (INCHES) (mm) ("A"+"B")	PAN FREEBD. READINGS 1st/2nd (INCHES) (mm)	GREEN VEGETATION AT STATION		ANEMOMETER (MILES) (km)	
				("A") AMOUNT ADDED	("A") AMOUNT REMOVED (NEGATIVE NO.)				HEIGHT	% COVER	READING	CHANGE
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Figure D-7. PAN EVAPORATION RECORD AT FLOOD IRRIGATED STATION (FOR HOOK GAUGE READINGS)

STATION NAME ______________________ **YEAR** __________

DATE	TIME	OBSERVER	AGENCY	HOOK GAGE READINGS (INCHES) (mm)				("B") PPTN. (INCHES) (mm)	PAN EVAP (INCHES) (mm) ("A"+"B")	PAN FREEBD. READINGS 1st/2nd (INCHES) (mm)	GREEN VEGETATION AT STATION		ANEMOMETER (MILES) (km)	
				PREVIOUS READING	1st READING	DIFFER ("A")	2nd READING				HEIGHT	% COVER	READING	CHANGE
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Explanation of Terms and Abbreviations Used in Data Collection Forms

Observer. Use initials.

Previous Reading. - Last pan water level reading obtained on previous observation date, following the addition or removal of water. This reading is the same as "2nd Reading" on data form from the previous observation. Reading is in inches and hundredths.

1st Reading. - This is the first pan water level reading obtained prior to adding or removing water from the pan. Reading is in inches and hundredths.

Differ. - Difference. When "1st Reading" is subtracted from "Previous Reading" the change in pan water level since the last servicing (difference) is computed. This can be a negative number if rainfall since the last servicing exceeded evaporation. Reading is in inches and hundredths.

2nd Reading. - If after the "1st Reading" is obtained, the pan water level needs to be adjusted by the addition or removal of water, a second reading is taken after the adjustment has been made. Reading is in inches and hundredths.

Pptn. - Precipitation. Reading is in inches and hundredths.

Pan Evap. - Pan Evaporation. Pan evaporation is computed by adding Column "A" and Column "B". A negative "pan evaporation" figure indicates an error.

% Cover. - The percentage of ground covered by green-growing vegetation as viewed from directly above.

Pan Freeboard Readings. - Pan freeboard is the distance from the pan rim down to the water surface in inches and tenths, as measured with a clean rain gauge stick.

APPENDIX E

ONE-GALLON CAN EVAPORIMETER

APPENDIX E. ONE-GALLON CAN EVAPORIMETER

The Department of Water Resources has developed an inexpensive 1-gallon can evaporimeter for use in transect evaporation studies (Calif. Dept. of Water Resources, 1976). The evaporimeter was adapted from a No. 10 1-gallon tin food can to obviate the need for hauling large quantities of water to remote areas. The evaporation rate from the can, which is galvanized and insulated (Figure E-1), is about equal to that of a Class "A" evaporation pan. Servicing is required only once a month, because the evaporimeter is equipped with a flexible plastic water supply bag that maintains a constant supply of water during the period of operation.

The bag is contained in the "water supply box" shown in Figure E-2. As shown, the bag is installed about 4 feet from the can, to which it is connected with a short length of plastic tubing. As water evaporates from the can, water is automatically fed from the flexible plastic bag into the can, thus stabilizing the water level in the can. Conversely, rain falling into the can, rather than causing an overflow, causes the water to back out through the tubing and into the storage bag.

The top of the can is covered with a 1-inch wire-mesh hardware cloth to keep birds from drinking the water. However, small insects, e.g., bees and wasps, can also remove significant quantities of water. To counter this, a second can containing water and red food coloring can be set up near by as a diversion.

The evaporation rate changes as the can water level changes. The change in rate has been determined experimentally to be about 1 percent for every 0.1 inch change in water level (Figure D-2). For example, a can with a 3-inch freeboard will have an evaporation rate about 10

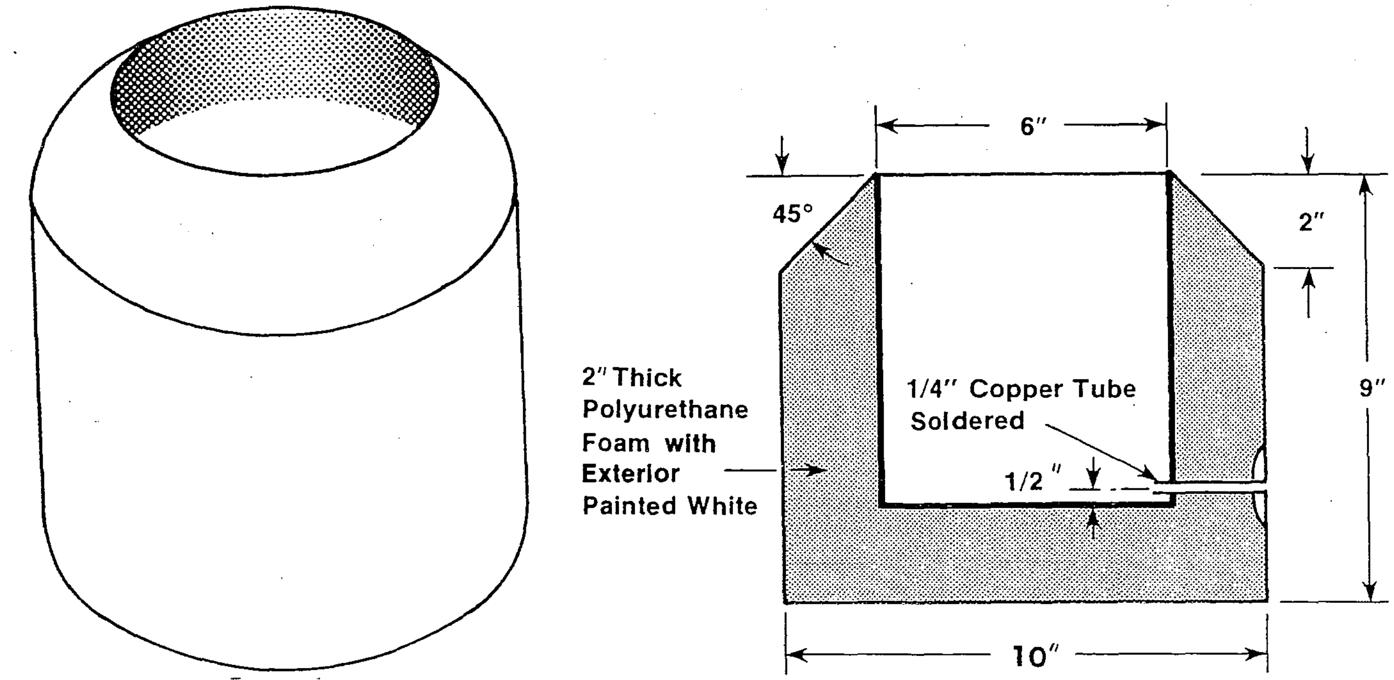


FIGURE E-1. ONE-GALLON-CAN EVAPORIMETER, CROSS SECTION

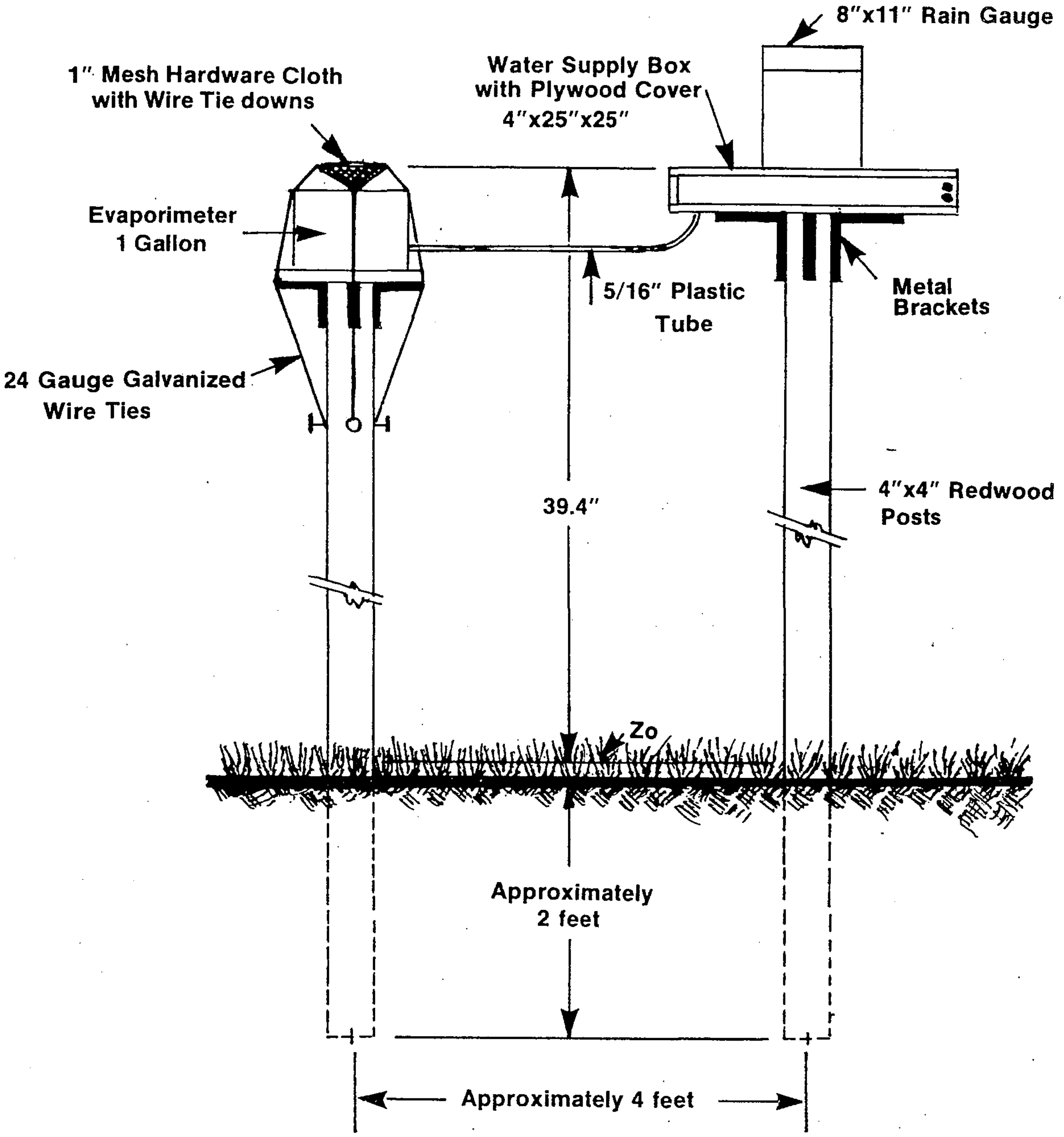


FIGURE E-2. ONE-GALLON-CAN EVAPORIMETER, STATION DETAIL percent (actual 8 percent) lower than a can with a 2-inch freeboard. Therefore, to obtain comparable readings from a network of evaporimeters, the cans must be operated with the same water level.

Siting and Servicing

The evaporimeter must be sited where it will be fully exposed to predominant winds, and the can must be upwind of the water supply box (see "Station Siting Recommendations" in Appendix D). The servicing of evaporimeters at the end of an operating period requires less than 10 minutes of field time at each site. Prior to field servicing, an operator fills a bag with water (for each station), weighs it on a platform scale, and records the weight on the form shown in Figure E-3. Each water-supply bag is then transported in a canvas bag, similar to those used by geologists for collecting rocks and gravel.

At each field site, the operator removes the wire mesh screen from the evaporimeter and lays a specially designed piece of plywood, with a 4-inch diameter hole in the center, over the top of the can. The plywood supports a micrometer hook gage, with which the operator measures the water level in the can.

The next step is to close the water shutoff valve, which is part of the water supply bag, and disconnect the water supply line. The water remaining in the can is discarded, since it has been measured by the hook gage. The operator now removes the water supply bag, which will be weighed at headquarters. The reading from the hook gage, and the difference in weights of the bag at the start of and following the operating period, plus any precipitation that fell, reveals the evaporative demand at each station.

To restart the station, the operator installs a new pre-weighed bag in the water supply box, attaches the water supply line and the lid, and opens the flow valve. After attaching the wire screen on top of the can, the operator can leave the site. Unattended, the can will fill with water to the predetermined level and will stabilize within a few minutes.

The cost of materials for a 1-gallon can evaporimeter station is about $33 (1985 prices). Constructing and installing a station requires only about 6 worker-hours. About 2 worker-hours per station, plus travel time, are required to fill and weigh a water bag, service a station, reweigh the returned bag, and perform the data reduction.

The minievaporimeter provides an efficient and relatively inexpensive tool for determining variations in evaporative demand and, thus, evapotranspiration over short distances.

FIGURE E-3. ONE-GALLON CAN EVAPORIMETER RECORD

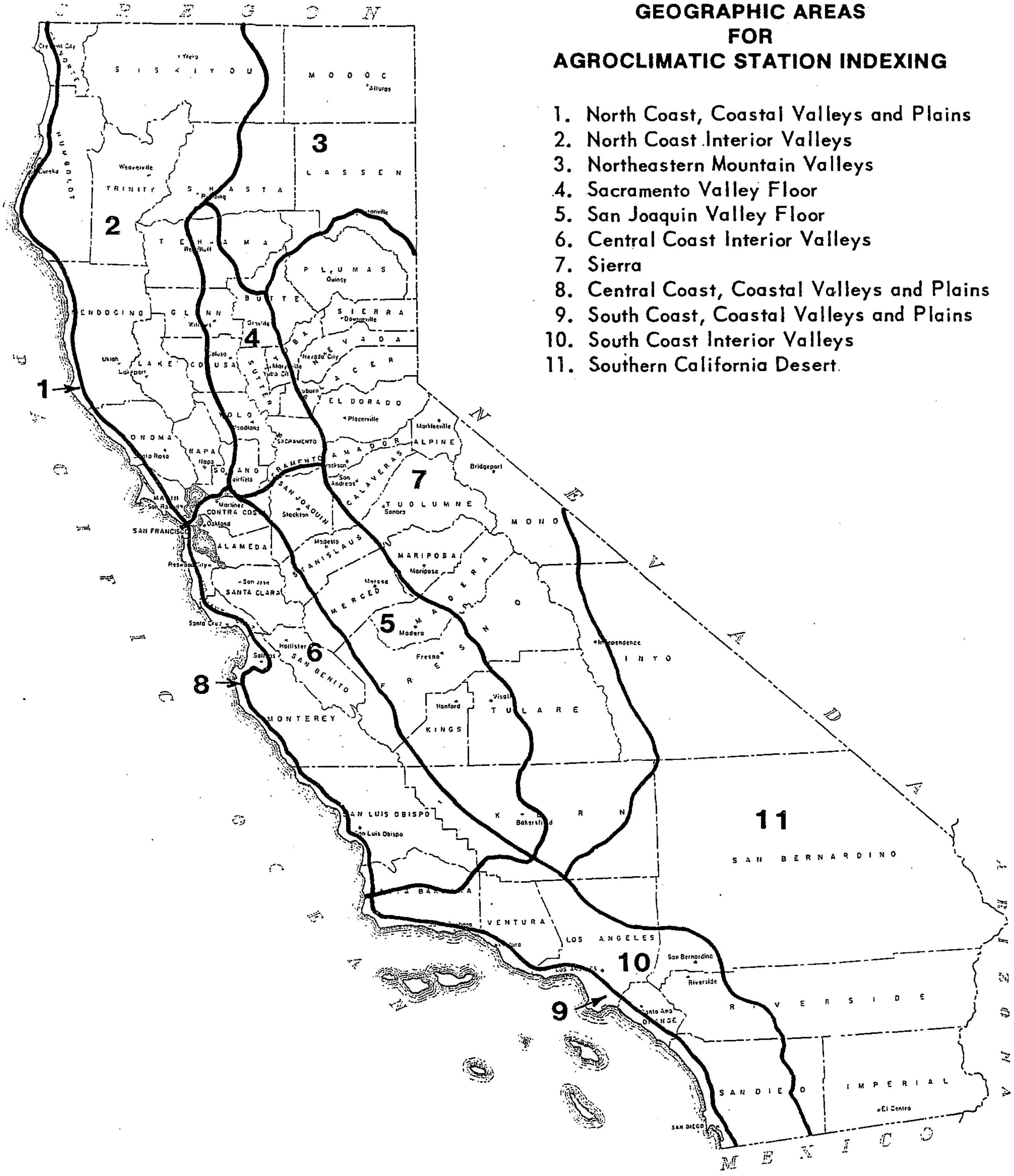
			WATER SUPPLY BAG					CAN (INCHES)			("E") SYSTEM CHANGE ("B"—"D") (INCHES)	("F") PPTN. (INCHES)	EVAPORATION		% GREEN COVER	REMARKS
				WEIGHT (kg)			("B") EQUIV. INCHES ("A"× 2.161)	FREE-BOARD (BEGIN / END)	("C") HOOK GAGE READING	("D") STORAGE ("C"+ 2.25)			FOR PERIOD ("E"+"F") (INCHES)	MONTHLY TOTAL (INCHES)		
DATE	TIME	OBSERVER	NUMBER	START OF PERIOD	END OF PERIOD	("A") CHANGE										

APPENDIX F

INDEX TO AGROCLIMATIC STATIONS

GEOGRAPHIC AREAS FOR AGROCLIMATIC STATION INDEXING

1. North Coast, Coastal Valleys and Plains
2. North Coast Interior Valleys
3. Northeastern Mountain Valleys
4. Sacramento Valley Floor
5. San Joaquin Valley Floor
6. Central Coast Interior Valleys
7. Sierra
8. Central Coast, Coastal Valleys and Plains
9. South Coast, Coastal Valleys and Plains
10. South Coast Interior Valleys
11. Southern California Desert



APPENDIX F

INDEX TO AGROCLIMATIC STATIONS*

Area / Station[1]	Observer	County	Location		Elev., Feet M.S.L.	Environment	Instrumentation			Remarks
			Township, Range Section, Tract[2]	Base & Meridian			Evap Pan[3]	Atmometers	Solar Rad.[4]	
NORTHEASTERN MOUNTAIN VALLEYS										
Fleming F&G[5]	DFG[5]	Lassen	T29N/R15E, Sec.21N	MD[6]	4,000	Dryland	X			(Wendel 4W) Protected environment
Glenburn 0.3SE	CE[7]/SCS[8]	Shasta	T37N/R4E, Sec. 10J	MD	3,310	Irrigated	X			Grass pasture
Susanville 2SE	SCS	Lassen	T29N/R12E, Sec.3D	MD	4,130	Irrigated	X			Grass pasture
Susanville 3SE	SCS	Lassen	T29N/R12E, Sec. 9H	MD	4,150	Irrigated	X			Native grass pasture
Tulelake 3NE	SCS	Modoc	T48N/R5E, Sec.18	MD	4,040	Irrigated	X			Grass pasture
NORTH COAST - COASTAL VALLEYS AND PLAINS										
Ferndale 1NW	Private[9]	Humboldt	T3N/R2W, Sec. 34R	H[10]	10	Natural high water table	X			Grass pasture
NORTH COAST INTERIOR VALLEYS										
Etna 5SE	CE/SCS	Siskiyou	T4IN/R9W, Sec. 23A	MD	2,860	Irrigated	X			Grass pasture
Grenada	CE	Siskiyou	T44N/R6W, Sec. 22H	MD	2,555	Irrigated	X			Grass pasture
Upper Lake 1SE	DWR	Lake	T15N/R9W, Sec. 7R	MD	1,330	Irrigated	X			Grass pasture
Upper Lake 2SE	CE/DWR[11]	Lake	T15N/R9W, Sec. 20F	MD	1,325	Irrigated	X			Grass pasture
SACRAMENTO VALLEY FLOOR										
Davis 2W	UC[12]	Yolo	T8N/R2E, Sec. 17K	MD	60	Irrigated	X		X	Turfgrass - ET tank location
Gerber 1SW	[13]	Tehama	T25N/R3W, Sec. 2Q	MD	250	Irrigated	X		X	Grass pasture
Nicolaus 3SE	DWR	Sutter	T12N/R4E, Sec. 20J	MD	32	Irrigated	X			Grass pasture
Rio Vista 5S	DWR	Sacramento	T3N/R3E, Sec. 19L	MD	-2	Natural high water table	x			Grass pasture
SAN JOAQUIN VALLEY FLOOR										
Bakrsfld 10NW	DWR	Kern	T28S/R27E, Sec. 18D	MD	495	Irrigated	X	X	X	Grass pasture
Fresno St. U.	DWR	Fresno	T13S/R20E, Sec. 12C	MD	340	Irrigated	X	X		Grass pasture
Oakley 1NE	WWA[14]	Contra Costa	T2N/R2E, Sec. 24K	MD	4	Irrigated	X			Grass pasture
Thornton 5S	CE/SCS	S.Joaquin	T14N/R5E, Sec. 34F	MD	5	Irrigated	X			Grass pasture
Wasco 8SW	DWR	Kern	T20S/R23E, Sec. 36Q	MD	295	Irrigated	X	X	X	Grass pasture
White Slough STP[15]	DWR/CE	S.Joaquin	T3N/R5E, Sec. 24N	MD	5	Irrigated	X			Grass pasture
SIERRA NEVADA										
Cool 3ENE	GDPUD[16]	El Dorado	T12N/R9E, Sec. 10J	MD	1750	Irrigated	X			Grass pasture
CENTRAL COAST - COASTAL VALLEYS AND PLAINS										
Guadalupe	CE	S.Barbara	T10N/R35W, Sec. 14E	SB	110	Irrigated	X			Grass pasture
Santa Maria	CE	S.Barbara	T10N/R33W, Sec. 7N	SB	258	Irrigated	X			Grass pasture
San Jose UCFS[17]	UC	S.Clara	T7S/R1W, Sec. 15H	MD	125	Irrigated	X			Turfgrass test site

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*All footnotes are on the next page.

FOOTNOTES

1/Station name usually includes distance in air miles and compass direction from local post office.

2/Tract indicates the general location of the station within the section. To avoid confusion with numbers, the letters "I" and "O" are not used.

D	C	B	A
E	F	G	H
J	K	L	M
N	P	Q	R

3/Standard U. S. Weather Bureau Class "A" pan.

4/Total incoming solar radiation.

5/Department of Fish and Game.

6/Mount Diablo.

7/University of California, Cooperative Extension Farm Advisor.

8/U. S. Department of Agriculture, Soil Conservation Service.

9/Mr. V. H. Willson.

10/Humboldt.

11/California Department of Water Resources.

12/University of California, Department of Land, Air, and Water Resources.

13/Department of Water Resources, University of California Cooperative Extension, and U. S. Department of Agriculture Soil Conservation Service.

14/Oakley-Bethel Island Waste Water Management Authority.

15/Sewage treatment plant.

16/Georgetown Divide Public Utility District.

17/University of California (Deciduous Fruit) Field Station.

APPENDIX G

EVAPORATION PAN DATA

APPENDIX G
SUMMARY OF OBSERVED EVAPORATION FROM CLASS "A" PANS IN IRRIGATED GRASS PASTURE ENVIRONMENTS[1/]*

(inches)

(Page 1 of 4)

Station	Year of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mar-Oct	Jan-Dec
NORTH COAST - COASTAL VALLEYS AND PLAINS															
Ferndale 1 NW[2/]	1979	-	-	-	-	-	-	5.14	5.09	4.04	-	-	-	-	-
	1980	-	2.29	3.53	-	-	5.33	7.06	4.16	4.81	-	-	1.74	-	-
	1981	-	-	2.33	3.56	4.81	5.28	5.13	4.10	4.33	2.49	-	-	32.03	-
	1982	-	1.76	-	4.13	4.76	4.31	4.73	3.98	3.68	3.04	-	-	-	-
	1983	-	-	-	3.33	4.44	4.59	5.59	4.32	4.15	2.93	-	-	-	-
	Average	-	2.02	2.93	3.67	4.67	4.88	5.53	4.33	4.20	2.82	-	1.74	33.03	-
NORTH COAST - INTERIOR VALLEYS															
Etna 5 SE[3/]	1978	-	-	-	-	-	8.04	8.16	6.99	4.28	-	-	-	-	-
	1979	-	-	-	4.00	7.25	8.42	9.00	-	5.13	-	-	-	-	-
	1980	-	-	-	-	-	-	8.76	7.78	-	-	-	-	-	-
	1981	-	-	-	-	-	-	8.42	9.26	5.50	-	-	-	-	
	Average	-	-	-	4.00	7.25	8.23	8.59	8.01	4.97	-	-	-	-	-
Grenada[4/]	1979	-	-	-	3.46	6.24	8.28	9.42	6.93	5.52	-	-	-	-	-
Upper Lake 1 SE[5/]	1970	-	-	-	-	6.95	8.62	10.75	-	-	-	-	-	-	-
	1971	-	2.31	-	4.48	6.10	-	10.20	9.33	6.41	4.22	2.14	-	-	-
	1972	1.07	1.22	3.45	4.94	6.74	-	8.72	-	-	-	-	-	-	-
	Average	1.07	1.77	3.45	4.71	6.60	8.62	9.89	9.33	6.41	4.22	2.14	-	53.23	-
Upper Lake 2 SE[6/]	1979	-	-	-	-	5.69	8.27	-	8.33	5.78	-	-	-	-	-
	1980	-	-	-	-	-	-	-	7.19	5.44	-	-	-	-	-
	1981	-	-	-	-	-	9.36	-	8.74	-	2.57	-	-	-	-
	1982	-	-	-	-	6.79	7.41	8.34	7.73	5.25	-	-	-	-	-
	1983	-	-	-	-	-	7.69	8.34	6.67	4.85	-	-	-	-	-
	Average	-	-	-	-	6.24	8.18	8.34	7.73	5.33	2.57	-	-	-	-
NORTHEASTERN MOUNTAIN VALLEYS															
Fleming F&G[7/]	1959	-	-	-	-	-	-	-	9.50	6.84	4.32	0.56	-	-	-
	1960	-	-	4.84	5.72	7.26	9.84	9.66	10.96	7.76	-	-	-	-	-
	1961	-	-	-	-	-	9.55	10.72	8.48	6.87	3.83	0.85	-	-	-
	1962	-	-	-	-	6.80	9.31	10.75	10.67	7.98	3.69	-	-	-	-
	1963	-	-	-	3.57	7.26	7.58	11.15	10.68	6.52	3.90	1.12	-	-	-
	1964	-	-	-	6.01	7.22	7.31	10.85	9.96	6.92	4.38	-	-	-	-
	1965	-	-	-	4.94	7.88	8.05	9.29	7.47	6.12	3.88	-	-	-	-
	1966	-	-	-	6.54	8.23	8.64	10.24	9.99	6.79	4.17	-	-	-	-
	1967	-	-	-	3.36	7.49	5.98	8.83	9.17	6.40	3.56	-	-	-	-
	1968	-	-	-	6.05	7.57	8.55	10.23	7.27	6.82	3.82	-	-	-	-
	1969	-	-	-	5.78	8.41	7.44	10.08	9.67	7.00	3.23	-	-	-	-
	1970	-	-	-	5.02	7.46	7.17	9.57	8.98	6.48	3.71	-	-	-	-
	1971	-	-	-	4.80	5.52	7.07	9.58	9.71	6.62	3.34	-	-	-	-
	1972	-	-	-	5.73	8.02	8.87	10.72	9.54	5.45	3.17	-	-	-	-
	1973	-	-	-	6.19	7.44	8.82	10.30	9.58	6.68	3.42	-	-	-	-
	1974	-	-	-	-	7.69	8.87	9.16	8.90	6.93	3.57	-	-	-	-
	1975	-	-	-	4.16	7.81	8.50	9.64	7.54	5.53	2.95				
	1976	-	-	-	5.58	8.92	8.59	9.50	6.14	5.20	3.01	-	-	-	-
	1977	-	-	-	6.61	5.07	8.00	9.29	7.97	5.99	3.57	-	-	-	-
	1978	-	-	-	4.60	7.30	8.41	9.58	9.07	5.43	4.45	-	-	-	-
	1979	-	-	-	5.07	8.00	9.59	9.90	8.13	6.78	3.36				
	1980				5.31	6.21	7.52	9.34	9.15	5.84	3.48	-	-	-	-
	1981	-	-	-	5.91	7.47	9.94	11.54	10.37	7.14	2.84	-	-	-	-
	1982	-	-	-	5.35	7.07	7.24	9.50	8.89	4.96	2.89	-	-	-	-
	1983	-	-	-	3.71	6.84	7.69	9.15	7.76	5.55	2.85	-	-	-	-
	Average	-	-	4.84	5.24	7.35	8.27	9.94	9.02	6.42	3.56	0.84	-	54.64	-
Glenburn 0.3 SE[3/]	1978	-	-	-	3.86	-	6.42	7.71	6.12	-	-	-	-	-	-
	1979	-	-	-	4.41	6.23	8.36	9.37	7.09	5.67	-	-	-	-	-
	1980	-	-	-	-	5.43	6.45	8.47	8.07	4.66	-	-	-	-	-
	1981	-	-	-	4.17	5.48	6.89	8.60	7.59	5.07	-	-	-	-	
	1982	-	-	-	-	6.45	6.31	7.96	-	-	-	-	-	-	-
	Average	-	-	-	4.15	5.90	6.89	8.42	7.22	5.13	-	-	-	-	-

*All footnotes are on page 4.

APPENDIX G (Continued)
SUMMARY OF OBSERVED EVAPORATION FROM CLASS "A" PANS IN IRRIGATED GRASS PASTURE ENVIRONMENTS[1]*

(inches)

(Page 2 of 4)

Station	Year of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mar-Oct	Jan-Dec
Susanville 3 SE[8]	1979	-	-	-	-	-	9.28	-	-	-	3.87	-	-	-	-
	1980	-	-	-	5.25	5.99	7.38	9.25	8.96	5.66	3.58	-	-	-	-
	1981	-	-	-	6.09	6.63	9.52	11.55	10.44	-	-	-	-	-	-
	Average	-	-	-	5.67	6.31	8.73	10.40	9.70	5.66	3.73	-	-	-	-
Susanville 2 SE[8]	1982	-	-	-	-	7.44	6.92	9.19	8.78	5.08	-	-	-	-	-
	1983	-	-	-	-	-	-	-	7.52	-	-	-	-	-	-
Tulelake 3 NE[8]	1981	-	-	-	-	-	7.62	8.72	8.71	5.44	2.52	-	-	-	-
	1982	-	-	-	4.51	-	-	8.17	7.44	4.79	2.68	-	-	-	-
	1983	-	-	-	3.80	-	7.15	7.84	6.71	5.38	-	-	-	-	-
	Average	-	-	-	4.16	-	7.39	8.24	7.62	5.20	2.60	-	-	-	-
SACRAMENTO VALLEY															
Davis 2 W[9]	1972	1.32	1.97	5.28	7.43	8.60	9.56	10.52	9.39	6.94	4.63	1.48	1.31	62.35	68.43
	1973	1.72	1.79	4.17	8.44	9.54	10.03	10.04	9.37	7.99	4.89	2.36	0.82	64.47	71.16
	1974	1.79	2.52	3.40	6.26	9.13	12.04	10.60	10.11	8.85	6.80	2.01	1.69	67.19	75.20
	1975	1.61	2.15	4.14	6.11	10.92	10.87	9.37	8.72	7.30	4.91	3.47	1.62	62.34	71.19
	1976	2.53	2.99	5.87	7.20	11.58	13.56	11.46	8.15	6.85	6.28	2.80	2.42	70.95	81.69
	1977	1.25	2.50	5.74	9.01	7.27	11.21	11.66	10.06	7.67	5.58	3.49	1.32	68.20	76.76
	1978	1.84	1.79	3.59	5.40	11.42	11.53	11.35	10.98	8.28	6.54	3.53	2.70	69.09	78.95
	Average	1.72	2.24	4.60	7.12	9.78	11.26	10.71	9.54	7.70	5.66	2.31	1.70	66.37	74.34
Gerber 1 SW[10]	1973	-	-	-	-	-	-	-	-	7.72	-	2.66	1.21	-	-
	1974	-	-	3.18	-	8.78	-	10.16	9.21	7.10	5.61	1.96	1.56	-	-
	1975	1.73	-	3.94	5.06	9.37	10.34	9.53	8.97	6.20	4.56	2.60	1.65	57.97	-
	1976	2.21	3.14	5.14	6.12	10.11	12.20	10.63	8.25	6.18	4.22	2.58	2.15	62.85	72.93
	1977	1.18	2.72	4.76	8.01	6.29	10.21	10.55	8.55	6.07	4.21	2.50	0.97	58.65	66.02
	1978	-	1.77	3.40	5.05	9.81	-	9.54	-	-	-	2.98	1.97	-	-
	1979	-	-	2.63	4.81	9.49	9.31	9.96	7.81	6.43	3.19	1.28	-	53.63	-
	1980	1.21	-	-	-	7.34	8.45	9.17	8.37	6.69	5.05	2.65	1.54	-	-
	1981	0.89	1.97	3.04	5.20	8.21	-	10.82	9.13	7.39	3.89	2.77	0.88	-	-
	1982	1.46	2.44	2.84	4.90	9.79	8.40	8.84	8.10	-	4.47	2.09	1.35	-	-
	1983	-	1.31	2.53	3.99	7.31	9.44	9.79	8.34	5.93	3.68	1.67	-	51.01	-
	Average	1.45	2.23	3.50	5.39	8.65	9.76	9.90	8.53	6.63	4.32	2.34	1.48	56.68	64.18
Nicolaus 3 SE[11]	1978	-	-	-	-	-	-	8.69	8.14	6.00	4.25	1.95	1.27	-	-
	1979	1.23	1.63	2.86	4.38	8.10	10.02	9.34	8.00	6.20	3.58	1.45	1.38	52.48	58.17
	1980	1.13	-	4.47	4.74	6.46	8.48	8.99	8.06	6.20	3.92	2.26	-	51.32	-
	1981	0.74	2.04	3.20	5.43	7.87	11.18	9.40	8.07	7.20	3.40	2.20	0.80	55.75	61.53
	1982	-	1.97	-	4.84	8.18	8.44	8.54	7.49	5.42	3.63	-	1.02	-	-
	1983	-	1.25	2.32	4.20	7.37	9.62	9.43	8.65	6.31	3.52	-	-	51.42	-
	Average	1.03	1.72	3.21	4.72	7.60	9.55	9.07	8.07	6.22	3.72	1.97	1.12	52.16	58.00
Rio Vista 5 S[11]	1977	-	-	-	-	-	-	12.34	10.21	-	5.61	3.27	-	-	-
	1978	-	1.55	3.50	4.74	9.74	11.12	11.98	11.54	7.76	6.06	-	2.02	66.44	-
	1979	-	2.99	3.83	5.58	9.04	11.87	11.57	11.20	9.36	5.56	1.91	-	68.01	-
	1980	-	-	5.34	5.56	7.55	9.90	11.40	10.79	8.31	5.44	3.25	1.56	64.29	-
	1981	1.43	2.42	3.53	6.94	10.64	-	-	-	9.13	4.82	-	-	-	-
	1982	-	2.55	3.65	6.38	10.38	9.97	11.63	10.58	7.53	4.62	-	1.90	64.74	-
	1983	-	1.69	-	5.35	9.23	10.79	10.55	10.51	8.21	4.83	2.01	1.26	-	-
	Average	1.43	2.24	3.97	5.76	9.43	10.73	11.58	10.81	8.38	5.28	2.61	1.69	65.94	73.91
SAN JOAQUIN VALLEY															
Bakersfield 10 NW[5]	1981	1.92	2.14	3.34	5.71	8.46	11.00	10.46	9.23	8.22	4.73	2.52	1.25	61.15	68.98
	1982	1.33	2.19	2.80	5.27	8.88	8.13	9.78	8.70	6.08	4.29	1.41	1.14	53.93	60.00
	1983	1.16	2.01	3.18	5.52	8.54	10.10	9.79	8.51	6.79	4.48	2.06	1.15	56.91	63.29
	Average	1.47	2.11	3.11	5.50	8.63	9.74	10.01	8.81	7.03	4.50	2.00	1.18	57.33	64.09
Fresno State University[5]	1973	1.42	1.74	3.10	5.89	8.75	10.09	11.32	9.28	7.29	4.88	2.39	0.94	60.60	67.09
	1974	1.28	2.03	3.44	5.29	9.00	10.77	10.76	9.16	7.11	4.04	1.83	0.96	59.57	65.67
	1975	1.25	2.60	3.63	5.34	8.56	10.82	10.59	8.90	6.64	4.83	-	1.35	59.31	-
	1976	1.61	2.43	4.96	6.31	10.55	11.16	12.54	8.82	6.56	4.31	2.10	1.21	65.21	72.56
	1977	0.88	2.65	4.17	-	6.74	-	11.06	9.98	6.94	4.53	2.16	-	-	-
	1978	1.09	1.47	2.59	3.99	8.59	9.51	10.18	9.58	5.93	4.45	1.98	1.00	54.82	60.36
	1979	1.23	1.95	3.35	-	9.05	10.20	10.44	9.55	7.25	4.26	2.57	1.68	-	-
	1980	0.82	1.88	3.65	5.20	7.73	10.17	10.78	9.69	7.27	4.14	2.88	1.14	58.63	65.35
	1981	1.71	2.01	3.27	6.05	9.60	12.84	11.61	9.58	7.50	3.86	1.92	1.05	64.31	71.00
	1982	1.20	2.02	3.08	5.36	8.58	9.13	10.85	9.32	6.24	4.12	-	1.13	56.68	-
	1983	1.20	1.95	2.79	4.94	8.28	10.31	10.46	8.64	6.40	3.95	1.83	1.06	55.77	61.81
	Average	1.24	2.07	3.46	5.37	8.68	10.50	10.96	9.32	6.83	4.31	2.18	1.15	59.43	66.07

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*All footnotes are on page 4.

APPENDIX G (Continued)

SUMMARY OF OBSERVED EVAPORATION FROM CLASS "A" PANS
IN IRRIGATED GRASS PASTURE ENVIRONMENTS[1]*
(inches)

(Page 3 of 4)

Station	Year of record	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mar-Oct	Jan-Dec
Oakley 1 NE[12]	1977	-	-	-	-	-	-	-	-	6.83	5.25	3.12	-	-	-
	1978	-	2.44	3.24	5.31	9.62	10.46	11.18	10.39	6.94	4.51	-	1.46	61.65	-
	1979	1.72	2.08	3.48	5.67	8.86	10.31	10.71	9.56	7.68	4.63	1.82	1.61	60.90	68.13
	1980	1.09	-	4.63	5.83	7.88	9.63	10.26	8.93	6.78	4.18	2.50	1.18	58.12	-
	1981	0.90	2.18	2.95	6.41	8.77	11.81	10.68	9.19	-	3.91	2.02	-	-	-
	1982	-	2.22	2.99	6.22	8.61	8.52	9.94	9.07	6.42	4.00	1.25	1.45	55.77	-
	1983	1.15	1.36	2.58	4.65	7.81	10.09	10.26	9.06	6.92	4.07	1.74	0.87	55.44	60.56
	Average	1.22	2.06	3.31	5.68	8.59	10.14	10.51	9.37	6.93	4.36	2.08	1.31	58.89	65.56
Thornton 5 S [10]	1977	-	-	-	-	-	-	-	-	5.72	4.45	2.54	1.64	-	-
	1978	-	2.44	3.48	4.78	9.22	9.13	9.43	8.57	6.05	4.42	1.91	1.18	55.08	-
	1979	-	2.20	3.47	4.98	8.90	10.69	9.41	-	6.74	3.67	1.65	-	-	-
	1980	-	-	4.52	5.33	-	-	-	-	-	-	-	-	-	-
	Average	-	2.32	3.82	5.03	9.06	9.91	9.42	8.57	6.17	4.18	2.03	1.41	56.16	-
Wasco 8 SW[5]	1975	1.45	2.41	4.79	5.52	8.10	10.42	10.16	9.30	6.73	4.78	2.20	1.34	59.80	67.20
	1976	1.62	2.63	4.31	5.50	8.56	9.82	10.31	8.48	5.90	4.12	1.59	1.33	57.00	64.17
	1977	0.81	2.62	4.05	7.66	6.96	9.06	8.58	7.59	5.90	4.01	1.80	1.77	53.81	60.81
	1978	1.05	1.17	2.60	4.24	7.52	8.62	8.82	8.13	5.13	3.94	1.87	0.86	49.00	53.95
	1979	1.48	1.97	3.59	5.96	8.82	8.64	8.66	8.18	6.15	4.28	2.19	1.78	54.28	61.70
	1980	0.97	1.85	3.52	5.30	7.52	8.45	8.97	8.08	6.33	4.95	2.83	1.04	53.12	59.81
	1981	1.52	1.97	3.40	5.94	9.01	11.11	-	-	-	-	-	-	-	-
	Average	1.27	2.09	3.75	5.73	8.07	9.45	9.25	8.29	6.02	4.35	2.08	1.35	54.91	61.70
White Slough STP[13]	1980	-	-	-	-	-	-	-	8.93	6.61	3.97	2.57	1.12	-	-
	1981	-	1.87	3.52	5.86	-	11.63	11.06	8.81	7.01	3.73	1.81	-	-	-
	1982	-	1.88	3.54	5.47	8.35	8.15	-	8.72	5.63	3.21	-	1.54	-	-
	1983	0.73	1.42	2.92	4.76	8.57	9.64	9.63	8.87	6.42	4.09	1.90	-	54.90	-
	Average	0.73	1.72	3.33	5.36	8.46	9.81	10.35	8.83	6.42	3.75	2.09	1.33	56.31	62.18
CENTRAL COAST - INTERIOR VALLEYS															
San Jose-U.C. Field Station[14]															
	1979	-	-	-	-	-	8.51	8.07	7.33	6.59	-	-	-	-	-
	1980	-	-	-	-	6.49	8.41	-	7.64	5.91	3.78	-	-	-	-
	1981	-	2.43	3.18	5.98	7.09	10.02	9.20	8.22	6.38	5.07	2.26	1.53	55.14	-
	1982	2.46	3.10	-	6.15	8.35	7.50	8.50	7.37	5.72	3.73	1.77	1.62	-	-
	1983	1.68	1.96	3.26	5.05	7.25	8.26	8.84	7.59	6.39	3.88	1.89	1.05	50.52	57.10
	Average	2.07	2.50	3.22	5.73	7.30	8.54	8.65	7.63	6.20	4.12	1.97	1.40	51.39	59.28
CENTRAL COAST - COASTAL VALLEYS AND PLAINS															
Guadalupe[4]	1979	-	2.39	3.37	4.86	6.64	6.24	7.06	-	5.53	4.03	2.60	3.30	-	-
	1980	1.54	3.05	4.46	5.13	5.64	6.89	6.37	5.34	4.43	3.93	2.93	2.39	42.19	52.10
	1981	2.43	2.70	3.77	5.77	7.73	7.51	6.94	6.22	5.20	4.61	2.92	2.09	47.75	57.89
	1982	2.35	2.93	3.60	5.03	5.64	7.56	7.09	6.48	5.83	5.60	3.18	2.98	46.83	58.27
	1983	-	-	2.89	4.68	6.58	6.61	7.90	6.42	5.52	4.75	3.06	-	-	-
	Average	2.11	2.77	3.62	5.09	6.45	6.96	7.07	6.12	5.30	4.58	2.94	2.69	45.19	55.70
Santa Maria[4]	1979	2.44	2.61	3.42	5.25	7.17	6.53	7.40	6.39	5.96	4.42	3.47	2.91	46.54	57.97
	1980	2.02	3.00	4.49	5.19	6.74	-	6.08	5.85	5.11	4.64	3.50	2.85	-	-
	1981	2.88	3.37	4.04	5.56	8.33	8.13	7.12	6.32	5.76	4.81	3.56	2.50	50.07	62.38
	1982	-	3.16	3.80	-	6.64	7.25	6.76	6.18	5.03	4.18	2.47	2.36	-	-
	1983	-	-	3.60	-	-	6.49	7.97	7.81	5.68	4.80	2.68	2.40	-	-
	Average	2.45	3.04	3.87	5.33	7.22	7.10	7.07	6.51	5.51	4.57	3.14	2.60	47.18	58.41
SIERRA															
Cool 3 ENE[15]	1978	-	-	-	-	-	8.8	-	-	5.8	4.6	-	-	-	-
	1979	-	-	-	-	-	8.8	8.7	6.8	-	4.0	-	-	-	-
	1980	-	-	3.8	-	-	7.5	-	-	-	-	-	-	-	-

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*All footnotes are on page 4.

FOOTNOTES

[1] Most stations names include distance in air miles and compass direction from local post office. Pans located in well-managed flood-irrigated grass pastures when available, except as noted. Quality of pasture site and, therefore, quality of pan data may be considered marginal from time to time at some locations of data collection for one or more of the following reasons: a) grasses outside station enclosure greater than 3 feet tall (will be cut for hay), thus reducing air movement over the pan; b) grasses within the station nearly as tall as the pan, causing a reduction of air movement over, under, and around the pan, and shading of the pan; c) pasture irrigation too infrequent, causing reducted grass ET and increased rate of pan evaporation; and d) noncropped, nonirrigated areas within 200 feet upwind of the pan.

[2] Natural high water table; irrigated pasture equivalent. Station serviced daily by Mr. V. H. Willson, private observer.

[3] Station serviced by U. S. Dept. of Agriculture (USDA) Soil Conservation Service, and University of California, Cooperative Extension farm advisor.

[4] Station serviced by University of California, Cooperative Extension farm advisor.

[5] Station serviced by Department of Water Resources (DWR).

[6] Station serviced by DWR and University of California, Cooperative Extension.

[7] Nonirrigated (sparse) salt grass (high water table may exist); tall cottonwood trees and single-story buildings upwind. Monthly pan evaporation at this site is very nearly equivalent to pan evaporation from flood-irrigated native grass sites in this area. Station serviced by California Department of Fish and Game.

[8] Station serviced by USDA, Soil Conservation Service.

[9] Station serviced by University of California. Data Contributed by W. O. Pruitt. Pan relocated about 300 feet south on 11/18/84, which reduced westerly upwind turf grass fetch to about 145 feet. Changed from USWB Class "A" pan painted aluminum to unpainted Class "A" monel-metal pan on June 1, 1976. Distance of northerly and westerly upwind turf grass fetch at original site diminished beginning in mid-1975. Composition of upwind fetch beyond turf grass changes from year to year due to planting of annual crops.

[10] Station serviced by DWR, University of California, Cooperative Extension farm advisor, and USDA, Soil Conservation Service.

[11] Station serviced by DWR and USDA, Soil Conservation Service.

[12] Station serviced by Oakley-Bethel Island Waste Water Management Authority.

[13] Station serviced by DWR and University of California, Cooperative Extension.

[14] Station serviced by University of California; grass turf irrigation scheduling test area.

[15] Station serviced by Georgetown Divide Public Utility District.

APPENDIX H
CROP APPLIED WATER DATA

APPENDIX H. CROP APPLIED WATER DATA

Appendix H contains summaries of measurements of irrigation water applied to specific crops in various parts of the State. The data are reported by individual Detailed Analysis Unit (DAU) within each Hydrologic Study Area (HSA). To find the location of each HSA and DAU see Figure H-1 (on the following page).

Some of the measurements were made directly by Department staff with the assistance of cooperating growers. However, most of the data were obtained from others who had installed measurement devices. To ensure that the data were as complete as possible, the Department canvassed farm advisors, agricultural consultants, representatives of irrigation equipment industry, U.S. Soil Conservation Service technicians, and employees of irrigation and water districts to identify growers who measure and maintain records of field irrigation deliveries. While contacting growers to obtain the data, the Department also obtained information on methods of water application, method and reliability of measurement, and other information needed to assess the adequacy of the data for the Department's needs. It was particularly important to assure that all irrigation water delivered to a field was measured and that all water measured was delivered only to the subject field of known size and planted with a single identified crop.

Measured data meeting these criteria are very limited in California. The summaries presented in this appendix represent years of intensive effort to locate and analyze data. Generally speaking, the measurements were made during the last ten years. The number given in the column titled "No. of Fields" is the number of samples. A sample was considered to be one field for one year. For example, one 100-acre field with three years of record was considered to be three samples, with a total of 300 acres. Also, three different fields for the same year were considered as three samples.

Although the data collected for the individual fields are considered to be highly reliable, users of this information should consider the following qualifications:

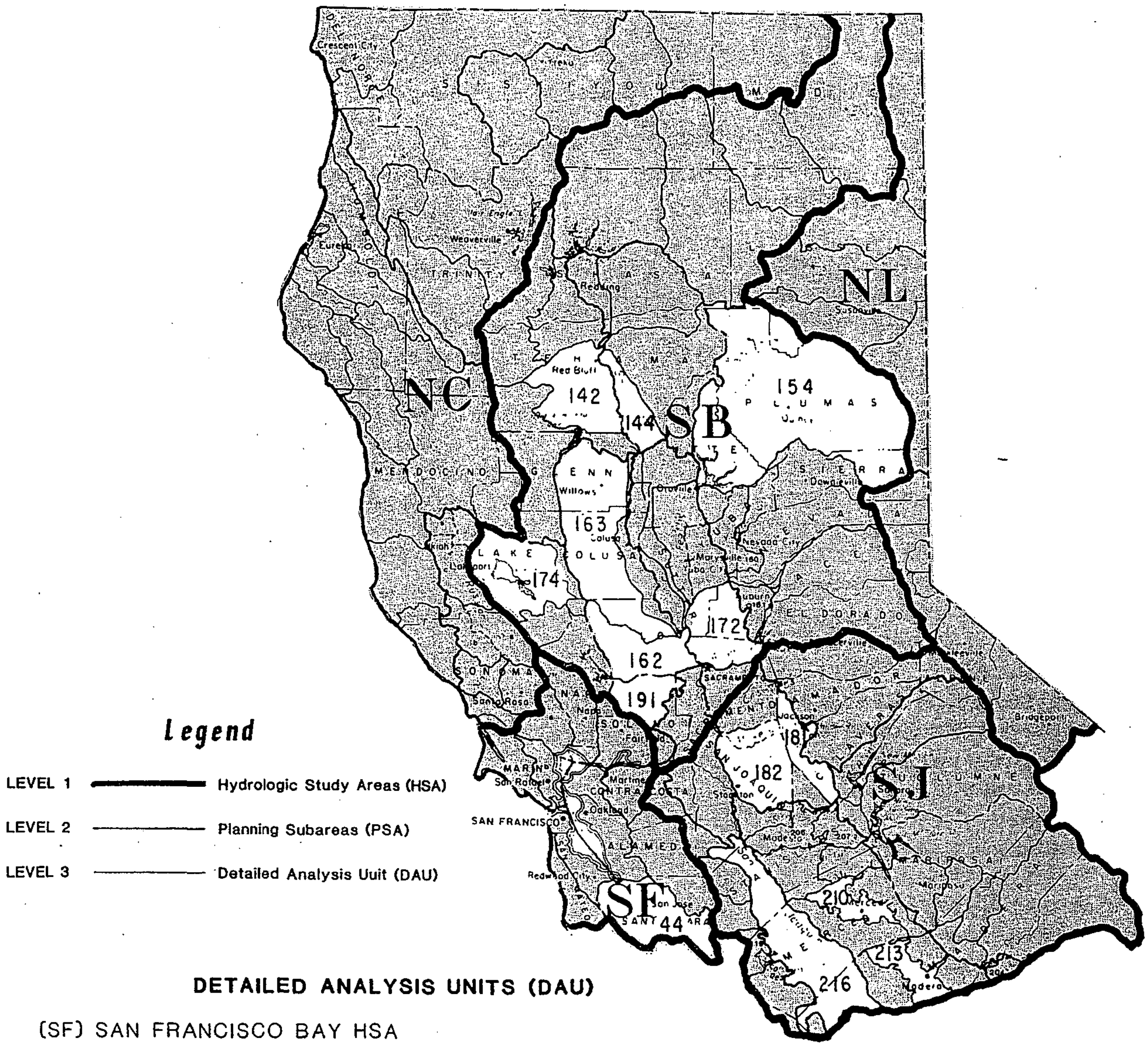
1. Most of the data were obtained from growers who maintained accurate records of field irrigation deliveries. Growers having that degree of interest in determining actual water deliveries to their crops may also extend that interest to other aspects of irrigation management. Thus, there may be a bias in the collected data toward the better managers.

2. In some irrigation and water districts, available surface water supplies are limited, thus controlling the amounts of water applied by growers relying on surface supplies only. Other districts, particularly during years of abundant water supplies, may through various methods such as water-pricing policies encourage "heavy" water applications to replenish ground water reservoirs.

The applied water data for rice, shown in Table H-12 (DAU 163) for 194 acres and 512 acres, were measured during a special low applied water test. Rice yields in the test area were average or above for the region.

In addition, those users who are interested in deriving average values for large areas should refer to the discussion in Chapter 2 regarding this subject.

LOCATIONS OF MEASURED IRRIGATION DELIVERIES



DETAILED ANALYSIS UNITS (DAU)

(SF) SAN FRANCISCO BAY HSA

44 – San Jose

(SB) SACRAMENTO HSA

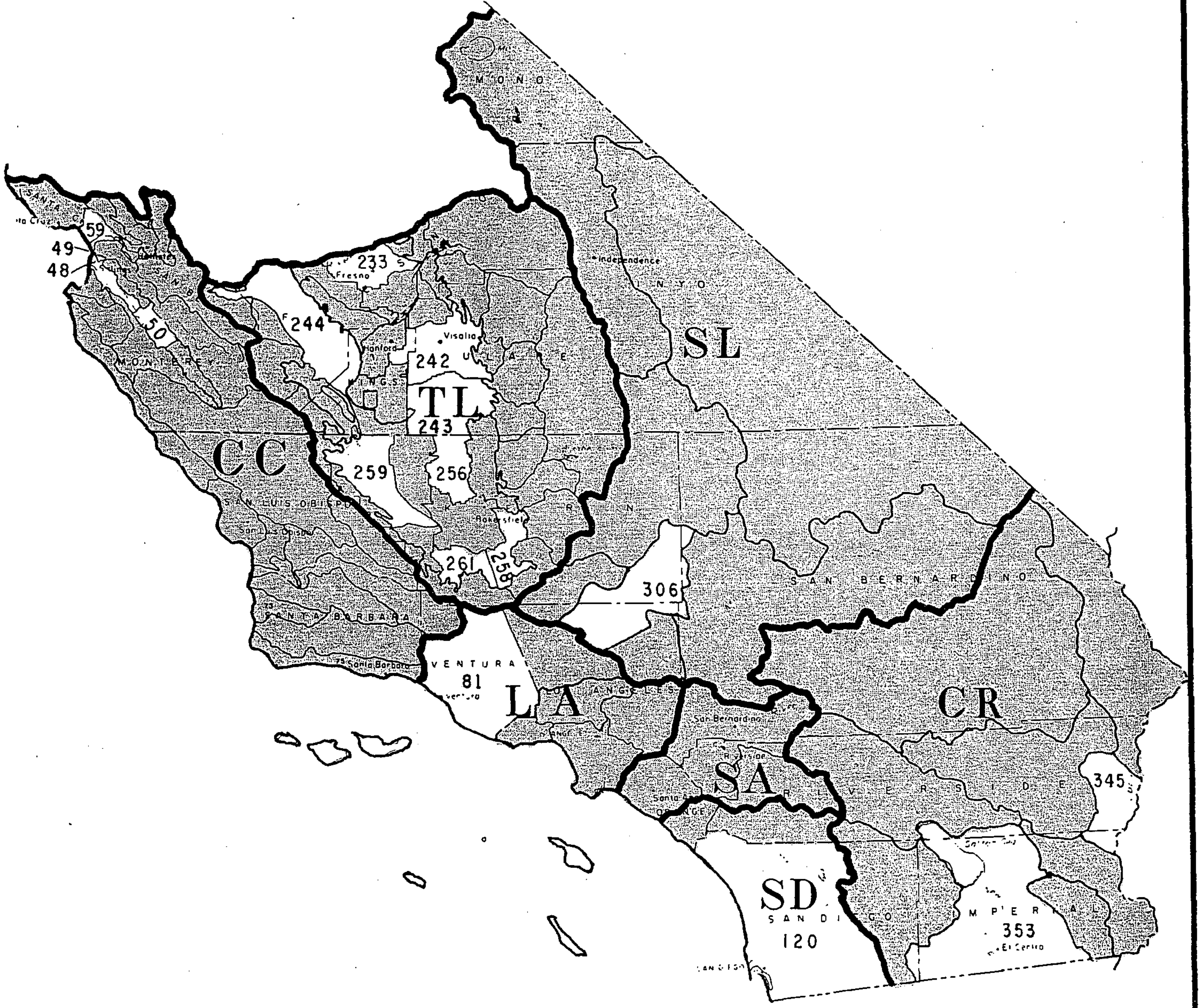
142 – Red Bluff–Orland
144 – Los Molinos
154 – Feather River
162 – Lower Cache Creek
163 – Willows–Arbuckle
172 – Placer
174 – Cache Creek
191 – Vacaville

(SJ) SAN JOAQUIN HSA

181 – Ione–Jenny Lind
182 – Lodi
210 – Merced
213 – Madera–Chowchilla
216 – West Side

Figure H-1, Sheet 2 of 2

LOCATIONS OF MEASURED IRRIGATION DELIVERIES (Cont.)



DETAILED ANALYSIS UNITS (DAU)

(CC) CENTRAL COAST HSA

48 – Pressure
49 – East Side
50 – Forebay
59 – Watsonville

(LA) LOS ANGELES HSA

81 – Ventura County

(SD) SAN DIEGO HSA

120 – San Diego County

(TL) TULARE LAKE HSA

233 – Fresno
242 – Kaweah Delta
243 – Tule Delta
244 – Westlands
256 – North Kern
258 – Arvin-Edison
259 – Antelope Plain
261 – Wheeler Ridge-Maricopa

(SL) SOUTH LAHONTAN HSA

306 – Rosemond-Palmdale

(CR) COLORADO RIVER HSA

345 – Palo Verde
353 – Imperial

TABLE H-1
AVERAGE MEASURED IRRIGATION DELIVERIES
SAN FRANCISCO HSA
DAU 44

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Apricots	Unknown	-	65	466	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Cherries	Unknown	-	62	624	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Pears	Unknown	-	89	2,451	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Prunes	Unknown	-	51	1,649	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Walnuts	Unknown	-	53	734	-	-	-	-	-	-	-	-	-	-	-	-	1.1
Mixed Orchard	Unknown	-	77	1,394	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Grains																	
Barley	Unknown	-	7	416	-	-	-	-	-	-	-	-	-	-	-	-	0.4
Field Crops																	
Sweet Corn	Unknown	-	16	202	-	-	-	-	-	-	-	-	-	-	-	-	2.5
Truck Crops																	
Cauliflower	Unknown	-	8	85	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Beans (bush)	Unknown	-	12	675	-	-	-	-	-	-	-	-	-	-	-	-	0.7
Cucumbers	Unknown	-	23	480	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Lettuce	Unknown	-	6	146	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Onions (green)	Unknown	-	13	417	-	-	-	-	-	-	-	-	-	-	-	-	4.4
Onions (dry)	Unknown	-	35	1,570	-	-	-	-	-	-	-	-	-	-	-	-	1.9
Peppers	Unknown	-	20	613	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Pumpkins	Unknown	-	13	171	-	-	-	-	-	-	-	-	-	-	-	-	1.4
Tomatoes (processing)	Unknown	-	44	1,809	-	-	-	-	-	-	-	-	-	-	-	-	1.8
Flowers	Unknown	-	134	816	-	-	-	-	-	-	-	-	-	-	-	-	4.9
Berries	Unknown	-	29	163	-	-	-	-	-	-	-	-	-	-	-	-	4.3
Mixed Row Crops	Unknown	-	208	6,259	-	-	-	-	-	-	-	-	-	-	-	-	2.3
Forage Crops																	
Alfalfa	Unknown	-	13	302	-	-	-	-	-	-	-	-	-	-	-	-	1.9
Pasture	Unknown	-	18	203	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Vineyard																	
Vineyard	Unknown	-	6	102	-	-	-	-	-	-	-	-	-	-	-	-	0.8

TABLE H-2
AVERAGE MEASURED IRRIGATION DELIVERIES
CENTRAL COAST HSA
DAU 48

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Truck Crops																	
Artichokes	Sprinkler	-	13	1,005	-	-	-	-	-	-	-	-	-	-	-	-	1.46
Broccoli	Sprinkler furrow	-	1	16	-	-	-	-	-	-	X	X[1]	-	-	-	-	1.26
Broccoli	Sprinkler furrow	-	1	39	-	-	-	-	-	-	-	-	X	X	X	X	.94
Cauliflower	Sprinkler furrow	-	6	80	X	X	X	X	-	-	-	-	-	-	-	-	1.05
Cauliflower	Sprinkler furrow	-	4	34	-	-	-	-	X	X	-	-	-	-	-	-	2.51
Cauliflower	Sprinkler furrow	-	7	96	-	-	-	-	-	-	X	X	-	-	-	-	1.58
Cauliflower	Sprinkler furrow	-	4	82	-	-	-	-	-	-	-	-	X	X	X	X	1.41
Celery	Sprinkler furrow	-	3	37	X	X	X	X	-	-	-	-	-	-	-	-	3.38
Celery	Sprinkler furrow	-	5	71	-	-	-	-	X	X	-	-	-	-	-	-	3.38
Lettuce	Furrow	-	15	253	X	X	X	X	-	-	-	-	-	-	-	X	1.14
Lettuce	Furrow	-	27	497	-	-	-	-	X	X	-	-	-	-	-	-	1.24
Lettuce	Furrow	-	4	93	-	-	-	-	-	-	X	X	-	-	-	-	.87
Spinach	Furrow	-	2	40	-	-	-	-	-	-	X	X	-	-	-	-	1.27

---

[1] "X" indicates the months when the first crop irrigation can be applied. The variability in the month of first irrigation is caused by rain. For example, drought years may allow a January planting, whereas during wet years, the planting date may be delayed several months until April. Also, the climate of this DAU allows the planting of up to three crops on one field during a calendar year.

TABLE H-3
AVERAGE MEASURED IRRIGATION DELIVERIES
CENTRAL COAST HSA
DAU 49

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN.	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Dry beans	Furrow	-	4	113	-	-	-	-	X[1]	X	-	-	-	-	-	-	1.31
Sugar beets	Furrow	-	9	366	X	X	X	X	-	-	-	-	-	-	-	X	2.65
Sugar beets	Furrow	-	1	18	-	-	-	-	-	-	-	-	-	-	-	-	3.09
Truck Crops																	
Lettuce	Furrow	-	5	207	X	X	X	X	-	-	-	-	-	-	-	X	0.91
Lettuce	Furrow	-	2	48	-	-	-	-	X	X	-	-	-	-	-	-	1.46
Potatoes	Furrow	-	6	144	-	-	-	-	X	X	-	-	-	-	-	-	1.64
Peas	Furrow	-	4	95	X	X	X	X	-	-	-	-	-	-	-	-	0.60
Broccoli	Sprinkler furrow	-	1	44	X	X	X	X	-	-	-	-	-	-	-	-	2.43
Broccoli	Sprinkler furrow	-	1	17	-	-	-	-	-	-	X	X	-	-	-	-	2.21
Parsley (seed)	Furrow	-	1	7	X	X	X	X	-	-	-	-	-	-	-	-	1.12
Carrots	Sprinkler furrow	-	1	22	X	X	X	X	-	-	-	-	-	-	-	-	3.68
Strawberries	Furrow	-	2	80	-	-	-	-	-	-	-	-	-	-	-	-	5.49
Forage																	
Alfalfa	Sprinkler	-	8	648	-	-	-	-	-	-	-	-	-	-	-	-	2.49
Deciduous Orchard																	
Apricots	Furrow	-	3	144	-	-	-	-	-	-	-	-	-	-	-	-	2.58
Walnuts	Furrow	-	2	8	-	-	-	-	-	-	-	-	-	-	-	-	1.86
Nursery																	
Carnations[2]	Unknown	-	5	7	-	-	-	-	-	-	-	-	-	-	-	-	6.31

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[1] "X" indicates the months when the first crop irrigation can be applied. The variability in the month of first irrigation is caused by rain. For example, drought years may allow a January planting, whereas during wet years, the planting date may be delayed several months until April. Also, the climate of this DAU allows the planting of up to three crops on one field during a calendar year.

[2] Greenhouse grown.

TABLE H-4
AVERAGE MEASURED IRRIGATION DELIVERIES
CENTRAL COAST HSA
DAU 50

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Truck Crops																	
Lettuce	Furrow	–	16	290	X	X	X	X	–	–	–	–	–	–	–	X[1]	1.50
Lettuce	Furrow	–	10	149	–	–	–	–	–	–	X	–	–	–	–	–	2.08
Lettuce	Furrow	–	1	9	–	–	–	–	–	–	X	X	–	–	–	–	1.20
Tomatoes	Furrow	–	1	15	X	X	X	X	–	–	–	–	–	–	–	–	2.77
Broccoli	Sprinkler furrow	–	1	15	X	X	X	X	–	–	–	–	–	–	–	X	2.53
Broccoli	Sprinkler furrow	–	1	15	–	–	–	–	–	X	–	–	–	–	–	–	4.74
Broccoli	Sprinkler furrow	–	6	120	–	–	–	–	–	–	X	X	–	–	–	–	2.67
Lima Beans	Furrow	–	1	18	–	–	–	–	–	–	–	–	–	–	–	–	2.39
Carrots	Sprinkler furrow	–	6	92	X	X	X	X	–	–	–	–	–	–	X	X	2.73
Carrots	Sprinkler furrow	–	2	28	–	–	–	–	X	X	–	–	–	–	–	–	2.38
Potatoes	Furrow	–	1	18	X	X	X	X	–	–	–	–	–	–	–	–	2.25
Potatoes	Furrow	–	1	17	–	–	–	–	X	X	–	–	–	–	–	–	2.14
Cucumbers	Furrow	–	1	20	–	–	–	–	X	X	–	–	–	–	–	–	2.70
Chili peppers	Furrow	–	1	80	X	X	X	X	–	–	–	–	–	–	–	–	4.51
Field Crops																	
Sugar beets	Furrow	–	2	50	X	X	X	X	–	–	–	–	–	–	–	X	2.13
Dry beans	Furrow	–	1	18	–	–	–	–	X	X	–	–	–	–	–	–	2.84
Dry beans	Furrow	–	1	17	–	–	–	–	–	–	X	X	–	–	–	–	1.99
Grains																	
Winter rye	Sprinkler	–	1	17	X	X	X	X	–	–	–	–	–	–	–	–	0.82
Green manure	Sprinkler furrow	–	1	20	–	–	–	–	–	–	–	–	–	–	X	X	0.68

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[1] "X" indicates the months when the first crop irrigation can be applied. The variability in the month of first irrigation is caused by rain. For example, drought years may allow a January planting, whereas during wet years, the planting date may be delayed several months until April. Also, the climate of this DAU allows the planting of up to three crops on one field during a calendar year.

TABLE H-5
AVERAGE MEASURED IRRIGATION DELIVERIES
CENTRAL COAST HSA
DAU 59

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Truck Crops																	
Lettuce	Furrow	–	3	77	–	–	0.3	0.1	0.3	0.2	–	–	–	–	–	–	0.9
Lettuce	Furrow	–	3	77	–	–	–	–	–	0.3	0.2	0.2	0.1	0.1	–	–	0.9
Lettuce	Furrow	–	3	77	–	0.2	0.1	0.0	0.3	0.1	–	–	–	–	–	–	0.7
Lettuce	Furrow	–	3	77	–	–	–	–	–	0.1	0.3	0.2	0.1	–	–	–	0.7
Lettuce	Furrow	–	3	77	–	–	0.1	0.1	0.4	T	–	–	–	–	–	–	0.6
Lettuce	Furrow	–	3	77	–	–	–	–	–	0.3	0.3	0.2	–	–	–	–	0.8
Lettuce	Furrow	–	2	42	–	–	0.2	0.1	0.4	0.1	–	–	–	–	–	–	0.8
Lettuce	Furrow	–	1	33	–	–	–	–	–	0.5	0.2	0.2	–	–	–	–	0.9
Lettuce	Furrow	–	3	77	–	0.1	0.0	0.5	0.3	0.1	0.1	–	–	–	–	–	1.1
Lettuce	Furrow	–	2	42	–	–	–	–	0.3	0.3	0.3	0.1	–	–	–	–	1.0

TABLE H-6
AVERAGE MEASURED IRRIGATION DELIVERIES
LOS ANGELES HSA
DAU 81

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Subtropical orchard																	
Avocadoes	Sprinkler	10-25	6	116	-	-	-	-	-	-	-	-	-	-	-	-	1.1
Avocadoes	Drip	10-15	2	47	-	-	-	-	-	-	-	-	-	-	-	-	0.9
Lemons	Furrow	9-25	10	338	-	-	-	-	-	-	-	-	-	-	-	-	1.0
Lemons	Drip	9	2	40	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Lemons	Sprinkler	25-30	12	594	-	-	-	-	-	-	-	-	-	-	-	-	1.4
Oranges	Furrow	25	4	128	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Truck Crops																	
Strawberries	Furrow	-	7	770	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Sweet Corn	Sprinkler	-	2	108	-	-	-	-	-	-	-	-	-	-	-	-	0.8

TABLE H-7
AVERAGE MEASURED IRRIGATION DELIVERIES
SAN DIEGO HSA
DAU 120

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Subtropical Orchard																	
Avocadoes	Mini-sprinkler	7-9	2	25	-	-	-	-	-	-	-	-	-	-	-	-	1.9[a]
Lemons	Sprinkler	12-15	8	680	-	-	-	-	-	-	-	-	-	-	-	-	0.6
Lemons	Mini-sprinkler	8	1	10	-	-	-	-	-	-	-	-	-	-	-	-	0.7[a]
Oranges	Sprinkler	15-20	17	461	-	-	-	-	-	-	-	-	-	-	-	-	1.0

[a] December irrigation, if any, not included.

TABLE H-8
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 142

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Prunes	Drip	13-25	2	138	-	-	-	-	-	0.5	0.9	0.4	0.3	-	-	-	2.1
Forage Crops																	
Pasture (mixed)	Border	-	8	840	T	T	0.1	0.3	0.5	0.9	0.9	0.8	0.5	0.2	T	-	4.2
Pasture (mixed)	Border	-	1	105	0.3	0.0	0.3	0.5	0.7	0.8	1.0	0.7	0.5	0.3	0.1	T	5.2[a]
Pasture (mixed)	Border	-	1	105	-	-	-	0.3	T	0.8	0.9	0.6	0.5	0.3	-	-	3.4[b]
Field Crops																	
Corn (field)	Furrow	-	2	156	-	-	-	0.1	1.3	1.3	1.4	0.3	-	-	-	-	4.4
Subtropical Orchard																	
Oranges	Hose-pull sprinkler	[c]	8	320	T	0.0	0.1	0.2	0.4	0.5	0.4	0.4	0.4	0.2	T	T	2.6
Oranges	Hose-pull sprinkler	[c]	1	40	0.2	0.0	0.1	0.4	0.5	0.7	0.4	0.4	0.3	T	0.2	0.1	3.3[a]
Truck Crops																	
Beans (dry)	Furrow	-	1	78	-	-	-	-	0.9	0.6	1.1	0.5	0.4	-	-	-	3.5
Cucumbers (seed)	Furrow	-	1	24	-	-	-	-	0.9	0.6	0.7	0.2	-	-	-	-	2.4
Onions (seed)	Sprinkler and furrow	-	1	20	-	-	-	-	-	-	1.0[d]	0.3	0.4	0.4	over wintered		2.1
Onions (seed)	Furrow	-	1	20	over wintered			0.3	0.3	1.2	0.3[d]	-	-	-	-	-	2.1

T = Trace (less than 0.05)

[a] All data from drought year 1976

[b] All data from wet year 1983

[c] Mature trees

[d] Planted in July, over wintered and harvested in July of following year

TABLE H-9
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 144

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Walnuts	Hose-pull sprinkler	[a]	8	784	T	T	T	0.2	0.4	0.4	0.5	0.4	0.1	T	-	-	2.0
Walnuts	Hose-pull sprinkler	[a]	1	98	0.5	0.3	0.4	0.4	0.5	0.4	0.6	0.7	-	-	-	-	3.8[b]
Walnuts	Hose-pull sprinkler	[a]	1	98	-	-	-	-	T	0.3	0.3	0.3	-	-	-	-	0.9[c]
Walnuts	Sprinkler	[a]	7	700	0.1	0.0	0.1	0.1	0.2	0.6	0.7	0.6	0.1	-	-	T	2.5
Walnuts	Sprinkler	[a]	1	100	0.6	T	0.2	04	0.5	0.6	0.7	0.6	0.3	-	-	-	3.9[b]
Truck Crops																	
Beans (dry)	Furrow	-	1	85	-	-	-	-	0.4	0.8	0.7	1.0	-	-	-	-	2.9

T = Trace (less than 0.05)

[a] Mature trees

[b] All data from drought year 1977

[c] All data from wet year 1983

TABLE H-10
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 154

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crop																	
Alfalfa	Center pivot sprinklers	-	9	2,065	-	-	-	T[1]	0.1	0.2	0.5	0.4	0.1	-	-	-	1.3
Turf	Center pivot sprinklers	-	1	120	-	-	-	-	0.4	0.4	0.6	0.5	T	-	-	-	1.9

[1] T = Trace (less than 0.05)

TABLE H-11
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 162

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Sugar Beets	Furrow	-	1	115	-	-	-	-	-	-	-	-	-	-	-	-	5.5[a]
Field Corn	Furrow	-	1	61	-	-	-	-	0.2	1.3	1.6	0.6	-	-	-	-	3.7
Grains																	
Wheat	Furrow	-	2	190	-	-	0.7	0.7	1.0	-	-	-	-	-	-	-	2.4[b]
Truck Crops																	
Garlic	Furrow	-	1	49	-	-	-	0.5	0.9	-	-	-	-	-	-	-	1.4
Tomatoes (processing)	Furrow	-	1	115	-	-	-	-	-	-	-	-	-	-	-	-	2.9
Tomatoes (processing)	Furrow	-	3	270	-	-	-	-	0.7	0.7	0.7	0.2	-	-	-	-	2.3

[a] All data for drought year 1976.

[b] Includes data for drought year 1976.

TABLE H-12
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 163

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Almonds	Sprinkler	[a]	5	1,720	-	-	-	-	-	-	-	-	-	-	-	-	1.7
Almonds	Sprinkler	[a]	5	868	-	-	0.3	0.3	0.2	0.4	0.4	0.0	0.0	0.2	T	0.0	1.8
Forage Crops																	
Alfalfa	Center-pivot sprinkler	-	2	340	-	-	-	0.2	0.4	0.3	0.5	0.4	0.2	0.4	-	-	2.4
Alfalfa	Border	-	2	300	-	-	0.5	0.5	0.4	0.8	0.8	0.8	0.7	T	-	-	4.5
Field Crops																	
Corn (field)	Furrow	-	1	71	-	-	-	-	-	0.8	0.9	0.3	-	-	-	-	2.0
Rice																	
Rice	Flood	-	6	512	-	-	-	0.2	1.2	1.1	1.2	1.0	0.1	-	-	-	4.8
Rice	Flood	-	6	512	-	-	-	0.2[b]	1.1[b]	0.9[b]	1.1[b]	0.8[b]	-0.3[c]	-			3.8[b]
Rice	Flood	-	2	194	-	-	-	-	1.4[d]	0.8[d]	1.1[d]	1.0[d]	0.1[d]	-			4.4[d]
Rice	Flood	-	2	194	-	-	-	-	1.3[e]	0.6[e]	1.0[e]	1.0[e]	-0.3[c]	-			3.6[e]
Rice	Flood	-	8	899	-	-	-	-	-	-	-	-	-	-	-	-	7.0[f]
Truck Crops																	
Tomatoes (processing)	Furrow	-	1	100	-	-	-	-	1.4	1.0	0.9	0.3	-	-	-	-	3.6

T = Trace (less than 0.05)

[a] Mature trees.

[b] Net applied: applied water minus outflow water = water available for crop ET, deep percolation, and as ponded water within soil profile and paddy.

[c] When ponded water is dumped at end of growing season, negative net applied water data are created because applied water is less than paddy outflow.

[d] All data from wet year 1983.

[e] Net applied (see footnote b) for wet year 1983.

[f] Data contributed by K. K. Tanji, Department of Land, Air, and Water Resources, University of California, Davis.

TABLE H-13
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 172

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage																	
Mixed Pasture	Border	-	1	110	-	-	-	-	0.2	0.7	1.1	0.9	0.6	0.2	-	-	3.7

TABLE H-14
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 174

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Pears	Sprinkler	[a]	2	57	-	-	-	0.1	0.3	0.6	0.9	0.5	0.2	-	-	-	2.6

[a] Mature trees.

TABLE H-15
AVERAGE MEASURED IRRIGATION DELIVERIES
SACRAMENTO HSA
DAU 191

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Almonds	Sprinkler	-	45	1,338	-	-	-	-	-	-	-	-	-	-	-	-	1.5
Pears	Sprinkler	-	23	993	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Plums	Sprinkler	-	8	261	-	-	-	-	-	-	-	-	-	-	-	-	1.2
Walnuts	Sprinkler	-	5	112	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Miscellaneous	Sprinkler	-	41	1,507	-	-	-	-	-	-	-	-	-	-	-	-	1.4
Field Crops																	
Beans	Furrow	-	110	6,008	-	-	-	-	-	-	-	-	-	-	-	-	2.4
Corn (field)	Furrow	-	169	10,199	-	-	-	-	-	-	-	-	-	-	-	-	3.4
Corn (sweet)	Furrow	-	14	506	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Grain (sorghum)	Furrow	-	3	292	-	-	-	-	-	-	-	-	-	-	-	-	4.0
Sugar Beets	Furrow	-	100	6,032	-	-	-	-	-	-	-	-	-	-	-	-	4.0
Sunflowers	Furrow	-	17	880	-	-	-	-	-	-	-	-	-	-	-	-	2.9
Forage Crops																	
Alfalfa	Border	-	39	1,880	-	-	-	-	-	-	-	-	-	-	-	-	3.7
Pasture	Border	-	37	716	-	-	-	-	-	-	-	-	-	-	-	-	2.9
Rice																	
Rice	Flood	-	2	102	-	-	-	-	-	-	-	-	-	-	-	-	7.1
Truck Crops																	
Melons	Furrow	-	29	1,040	-	-	-	-	-	-	-	-	-	-	-	-	2.9
Onions	Furrow	-	8	164	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Peppers	Mixed	-	8	413	-	-	-	-	-	-	-	-	-	-	-	-	3.8
Tomatoes (processing)	Furrow	-	142	8,613	-	-	-	-	-	-	-	-	-	-	-	-	2.8

TABLE H-16
AVERAGE MEASURED IRRIGATION DELIVERIES
SAN JOAQUIN HSA
DAU 181

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Pears	Sprinkler	8+	8	304	-	-	-	-	-	-	-	-	-	-	-	-	4.1
Subtropical Orchard																	
Kiwi	Sprinkler	-	10	127	-	-	-	-	-	-	-	-	-	-	-	-	4.0
Field Crops																	
Beans (dry)	Furrow	-	8	769	-	-	-	-	-	-	-	-	-	-	-	-	2.1
Corn (field)	Furrow	-	17	1,493	-	-	-	-	-	-	-	-	-	-	-	-	3.2
Sugar Beets	Furrow	-	19	1,467	-	-	-	-	-	-	-	-	-	-	-	-	3.1
Milo	Furrow	-	2	115	-	-	-	-	-	-	-	-	-	-	-	-	1.6
Forage Crops.																	
Alfalfa	Sprinkler	-	6	365	-	-	-	-	-	-	-	-	-	-	-	-	2.5
Alfalfa	Border	-	7	326	-	-	-	-	-	-	-	-	-	-	-	-	3.3
Pasture	Sprinkler	-	58	1,475	-	-	-	-	-	-	-	-	-	-	-	-	2.8
Pasture	Border	-	21	933	-	-	-	-	-	-	-	-	-	-	-	-	3.4
Sudan	Sprinkler	-	2	40	-	-	-	-	-	-	-	-	-	-	-	-	1.6
Sudan	Border	-	1	15	-	-	-	-	-	-	-	-	-	-	-	-	2.8
Vineyard																	
Vineyard	Sprinkler	3+	7	101	-	-	-	-	-	-	-	-	-	-	-	-	0.8
Vineyard	Drip	1-3	3	174	-	-	-	-	-	-	-	-	-	-	-	-	0.8

TABLE H-17
AVERAGE MEASURED IRRIGATION DELIVERIES
SAN JOAQUIN HSA
DAU 182

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Walnuts	Flood	[a]	7	430	-	-	-	-	-	-	-	-	-	-	-	-	2.6
Walnuts	Sprinkler	[a]	28	3,274	-	-	-	-	-	-	-	-	-	-	-	-	2.2
Walnuts and cherries	Flood	[a]	4	349[b]	-	-	-	-	-	-	-	-	-	-	-	-	2.7
Walnuts and cherries	Sprinkler	[a]	7	611[c]	-	-	-	-	-	-	-	-	-	-	-	-	3.4
Apples	Flood	1-3	3	95	-	-	-	-	-	-	-	-	-	-	-	-	1.6
Walnuts and cherries	Sprinkler	[a]	3	105[d]	-	-	-	-	-	-	-	-	-	-	-	-	2.4
Walnuts	Flood	2	1	35	-	-	-	-	-	-	-	-	-	-	-	-	2.7[f]
Miscellaneous	Sprinkler	[a]	3	20[e]	-	-	-	-	-	-	-	-	-	-	-	-	1.7
Field Crops																	
Beans (kidney)	Furrow	-	3	140	-	-	-	-	-	-	-	-	-	-	-	-	1.3
Sugar Beets	Furrow	-	2	100	-	-	-	-	-	-	-	-	-	-	-	-	2.4
Forage																	
Alfalfa	Furrow	-	2	70	-	-	-	-	-	-	-	-	-	-	-	-	3.0
Vineyard																	
Vineyard	Furrow	3+	12	360	-	-	-	-	-	-	-	-	-	-	-	-	1.6
Vineyard	Furrow	3+	2	20	-	-	-	-	-	-	-	-	-	-	-	-	1.7
Vineyard	Furrow	1	1	20	-	-	-	-	-	-	-	-	-	-	-	-	0.7
Vineyard	Furrow	2	1	20	-	-	-	-	-	-	-	-	-	-	-	-	0.7
Vineyard	Furrow	3	1	20	-	-	-	-	-	-	0.2	0.2	-	-	-	-	0.4[f]
Vineyard	Furrow	3+	1	10	-	-	-	-	-	0.4	[g]	0.5	-	-	-	-	0.9[f]

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[a] Mature trees.
[b] Walnuts at 320 acres and cherries at 29 acres.
[c] Walnuts at 560 acres and cherries at 51 acres.
[d] Walnuts at 45 acres and cherries at 60 acres.
[e] Walnuts at 6 acres and cherries at 12 acres.
[f] All data from wet year 1983.
[g] Included in August reading.

TABLE H-18
AVERAGE MEASURED IRRIGATION DELIVERIES
SAN JOAQUIN HSA
DAU 210

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crops																	
Alfalfa	Border	-	29	1,331	-	-	0.16	0.38	0.72	0.82	0.83	0.72	0.55	0.66	0.00	0.00	4.24
Pasture	Border	-	26	2,721	-	-	0.06	0.45	0.65	0.66	0.91	0.74	0.48	0.20	0.00	0.00	4.15
Field Crops																	
Beans (dry)	Furrow	-	3	79	-	-	-	-	0.71	0.74	0.76	0.46	0.00	-	0.00	-	2.67
Corn	Furrow	-	19	667	-	-	-	-	0.32	0.69	1.09	0.96	0.41	0.02	-	-	3.49
Cotton	Furrow	-	22	1,141	-	-	-	-	0.02	0.38	0.84	0.94	0.11	-	-	-	2.53
Grain sorghum	Furrow	-	1	46	-	-	-	-	-	-	0.63	0.76	0.00	-	-	-	1.39
Sudan	Furrow	-	3	75	-	-	-	-	-	0.89	0.77	0.08	0.39	-	-	-	2.13
Sugar beets	Furrow	-	2	83	-	-	0.17	0.00	0.24	0.66	1.29	1.16	0.26	-	-	-	3.78
Grains																	
Wheat and barley	Border	-	28	1,463	-	-	0.15	0.68	0.44	0.02	-	-	-	-	-	-	1.29
Rice	Contour border	-	26	13,014	-	-	-	0.23	1.62	1.20	1.44	1.35	0.42	0.01	-	-	6.27
Truck Crops																	
Bushberries	Furrow	-	1	25	-	-	-	0.79	0.59	0.67	0.83	0.59	0.47	0.24	-	-	4.18
Melons	Furrow	-	6	91	-	-	0.06	0.35	0.39	0.93	0.78	0.75	0.08	-	-	-	3.34
Peppers	Furrow	-	2	69	-	-	-	0.39	0.35	1.03	1.02	0.45	0.00	-	-	-	3.24
Sweet Potatoes	Furrow	-	7	203	-	-	-	0.00	0.10	0.54	0.77	0.78	0.34	-	-	-	2.53
Tomatoes (processing)	Furrow	-	2	108	-	-	-	0.00	0.25	1.16	1.07	0.39	-	-	-	-	2.87
Deciduous Orchard																	
Almonds	Border	-	20	1,718	-	-	0.02	0.50	0.59	0.60	0.64	0.66	0.12	0.14	-	-	3.27
Figs	Furrow	-	6	415	-	-	0.17	0.54	0.20	0.65	0.56	0.35	0.12	-	-	-	2.59
Peaches	Basin	-	4	256	-	-	0.00	0.54	0.66	0.97	1.05	0.57	0.23	0.09	-	-	4.11
Prunes	Basin	-	1	72	-	-	0.00	0.40	0.41	0.37	0.37	0.68	-	-	-	-	2.23
Walnuts	Border	-	5	229	-	-	0.00	0.49	0.55	0.90	0.68	0.59	0.25	0.02	-	-	3.48
Vineyard	Furrow	-	25	2,096	-	-	0.17	0.45	0.51	1.01	0.87	0.52	0.04	0.04	-	-	3.61

TABLE H-19
AVERAGE MEASURED IRRIGATION DELIVERIES[1]
SAN JOAQUIN HSA
DAU 213

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Cotton	Furrow	-	1	43	-	-	0.91	-	-	-	2.46	2.70	-	-	-	-	6.07
Vineyard	Furrow	-	13	181	-	-	0.13	0.26	0.43	0.31	0.53	0.43	0.15	0.02	0.07	0.00	2.33

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[1] Data abstracted from "Use of Water on Federal Irrigation Projects, Central Valley Project, 1967-1970," Summary Report, Volume 2, U. S. Bureau of Reclamation, August 1971.

TABLE H-20
AVERAGE MEASURED IRRIGATION DELIVERIES
SAN JOAQUIN HSA
DAU 216

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crops																	
Alfalfa	Border	-	3	448	-	-	-	-	-	-	-	-	-	-	-	-	5.30
Field Crops																	
Alfalfa seed[1]	Furrow	-	5	457	-	-	-	0.41	0.92	0.10	-	-	-	0.00	0.91	0.00	2.34
Corn	Furrow	-	1	49	-	-	-	-	-	-	-	-	-	-	-	-	3.90
Cotton[1]	Furrow	-	3	290	2.00	-	-	-	-	0.78	0.62	-	-	-	-	-	3.40
Sudan	Border	-	1	32	-	-	-	-	-	-	-	-	-	-	-	-	2.10
Sugar Beets	Furrow	-	1	57	-	-	-	-	-	-	-	-	-	-	-	-	3.70
Grains	Border	-	3	216	-	-	-	-	-	-	-	-	-	-	-	-	1.50
Truck Crops																	
Melons	Furrow	-	2	120	-	-	-	-	-	-	-	-	-	-	-	-	2.00
Tomatoes[1] (processing)	Furrow	-	4	535	-	-	1.30	0.48	0.72	0.82	0.62	0.12	-	-	-	-	4.06

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[1] Data abstracted from "Use of Water on Federal Irrigation Projects, Central Valley Project, 1967-1970," Summary Report, Volume 2, U. S. Bureau of Reclamation, August 1971.

TABLE H-21
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 233

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Deciduous Orchard																	
Almonds	Sprinkler	-	1	387	-	-	-	-	0.00	0.00	3.50	0.50	0.00	0.32	-	-	4.32
Peaches	Furrow	-	3	24	-	-	-	0.33	0.58	0.61	0.87	0.29	0.31	0.18	-	-	3.17
Plums	Furrow	-	3	12	-	-	-	0.40	1.05	0.99	1.02	0.99	0.73	0.27	-	-	5.45
Vineyards																	
Grapes	Furrow	1 yr	4	1,970	-	-	0.03	0.05	0.27	0.42	0.48	0.63	0.23	0.06	-	0.10	2.27
Grapes	Furrow	2 yrs	4	2,286	0.02	0.01	0.03	0.15	0.25	0.85	0.67	0.45	0.68	0.19	-	-	3.30
Grapes	Furrow	Mature	23	13,965	0.13	0.08	0.02	0.33	0.31	0.55	0.58	0.71	0.26	0.09	0.02	-	3.08

TABLE H-22
AVERAGE MEASURED IRRIGATION DELIVERIES[1/]
TULARE LAKE HSA
DAU 242

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crops																	
Alfalfa	Border	-	5	200	-	0.10	0.11	0.34	0.43	0.65	0.83	0.68	0.44	0.09	-	-	3.67
Pasture	Border	-	5	30	-	-	0.08	0.26	0.34	0.28	0.47	0.39	0.32	0.18	0.06	-	2.38
Field Crops																	
Beans (dry)	Furrow	-	3	59	-	-	-	0.41	0.28	0.47	0.74	0.34	0.09	-	-	-	2.33
Cotton	Furrow	-	7	191	-	-	0.11	0.10	0.18	0.59	0.71	0.43	0.19	-	-	-	2.31
Grain sorghum	Furrow	-	1	19	-	-	-	0.00	0.00	0.72	1.44	0.00	-	-	-	-	2.16
Truck Crops																	
Peppers	Furrow	-	2	10	-	-	0.26	0.38	0.67	0.54	0.69	0.39	0.20	-	-	-	3.13
Deciduous Orchard																	
Plums	Furrow	-	4	80	-	-	-	0.04	0.45	0.50	0.56	0.50	0.21	0.13	0.00	-	2.39
Prunes	Furrow	-	5	140	0.00	0.00	0.10	0.25	0.35	0.49	0.37	0.50	0.32	0.30	0.17	-	2.85
Subtropical Orchard																	
Citrus	Hose-pull sprinkler	-	17	884	-	0.01	-	0.07	0.17	0.27	0.31	0.36	0.28	0.20	0.12	0.06	1.85
Olives	Furrow	-	8	240	-	0.03	0.00	0.03	0.12	0.37	0.32	0.43	0.43	0.16	0.10	0.04	2.03

[1/] Surface supply from U. S. Bureau of Reclamation's Friant-Kern Canal. Does not include deliveries during 1976 and 1977 when surface supplies were limited.

TABLE H-23
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 243

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crops																	
Alfalfa	Border	-	1	40	-	-	-	0.50	0.49	0.95	0.86	0.49	0.47	0.43	-	-	4.19
Field Crops																	
Cotton	Furrow	-	1	77	-	-	-	0.36	0.17	0.81	0.39	0.48	0.10	0.00	0.00	0.00	2.31
Sugar beets	Furrow	-	1	190	-	-	0.03	0.28	0.02	0.41	0.58	0.49	0.11	0.00	0.00	0.00	1.92
Truck Crops																	
Melons	Furrow	-	1	190	0.00	0.00	0.22	0.00	0.39	0.49	0.40	0.05	1.51	0.73	0.66	0.00	4.45
Deciduous Orchard																	
Almonds	Border	-	6	189	0.00	0.31	0.33	0.94	1.03	1.12	1.08	0.54	0.04	1.02	0.12	0.00	6.53
Pistachios	Drip	-	6	238	-	-	-	-	-	-	-	-	-	-	-	-	1.20
Plums	Furrow	-	2	130	0.00	0.00	0.10	0.50	0.67	0.50	0.56	0.56	0.21	0.00	0.00	0.00	3.10
Pomegranates	Hose-pull sprinkler	-	3	60	-	-	-	-	-	-	-	-	-	-	-	-	1.96
Prunes	furrow	-	1	40	0.00	0.00	0.00	0.50	0.53	0.65	0.40	0.48	0.88	0.50	0.00	0.00	3.94
Subtropical Orchard																	
Citrus	Hose-pull sprinkler	1-3 yrs	37	898	-	-	-	-	-	-	-	-	-	-	-	-	1.22
Citrus	Hose-pull sprinkler	4-7 yrs	19	692	-	-	-	-	-	-	-	-	-	-	-	-	1.55
Citrus	Hose-pull sprinkler	mature	67	1,249	-	-	-	-	-	-	-	-	-	-	-	-	2.24
Citrus	Hose-pull sprinkler	mature	35	629	0.01	-	-	-	0.19	0.41	0.49	0.59	0.53	0.44	0.19	0.03	2.89
Citrus	Drip	mature	18	486	-	-	-	-	-	-	-	-	-	-	-	-	2.07
Citrus	Drip	mature	4	164	-	-	-	-	-	-	-	-	-	-	-	-	1.73
Olives	Furrow	mature	3	30	-	-	-	0.26	0.81	0.32	0.90	0.61	0.63	0.39	0.68	-	4.59
Olives	Hose-pull sprinkler	mature	12	1,229	-	-	-	-	-	-	-	-	-	-	-	-	2.20
Vineyard																	
Grapes	Furrow	mature	20	1,528	0.00	0.32	0.14	0.37	0.86	0.99	0.92	0.68	0.54	0.43	0.12	0.03	5.40
Grapes	Furrow	mature	24	3,816	-	-	-	-	-	-	-	-	-	-	-	-	2.90

TABLE H-24
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 244[1]

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Cotton	Furrow	-	14	2,546	-	-	-	-	0.00	0.34	0.48	0.64	0.05	0.08*	0.22*	0.52*	2.33
Cotton	sprinkler	-	10	1,881	-	0.05	-	-	0.11	0.43	0.52	0.50	0.02	-	0.20*	0.13*	1.96
Safflower	Furrow	-	1	65	-	0.00	0.49	0.39	0.30	0.00	0.00	0.00	-	-	-	-	1.18
Sugar beets	Furrow	-	2	320	-	-	-	0.00	0.56	0.88	0.48	0.00	0.00	0.00	0.00	0.58	2.50
Grains																	
Barley	Furrow	-	13	1,819	-	0.05	0.34	0.49	0.20	-	-	-	-	-	0.09	0.11	1.28
Barley	Sprinkler	-	1	165	0.77	-	0.00	0.46	0.00	-	-	-	-	-	-	-	1.23
Wheat	Furrow	-	2	297	-	-	0.28	0.59	0.13	-	-	-	-	-	-	0.84	1.84
Wheat	Sprinkler	-	1	128	-	-	0.17	0.58	0.35	-	-	-	-	-	0.54	0.54	2.18
Truck Crops																	
Tomatoes (processing)	Furrow	-	5	602	-	-	0.26	0.21	0.56	0.36	0.36	0.13	-	-	-	-	1.88
Tomatoes (processing)	Sprinkler & furrow[2]	-	8	950	-	-	0.09	0.06	0.44	0.56	0.30	0.07	0.01	-	-	0.18	1.71

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[1] Area from which irrigation deliveries were obtained is underlain by perched water at shallow depths.

[2] Germination and first crop irrigations were with hand-move sprinklers; irrigations after flowering were by furrow. Data for one field were abstracted from "Use of Water on Federal Irrigation Projects, Central Valley Project, 1967-1970," Summary Report, Volume 2, U. S. Bureau of Reclamation, August 1971.

*Preirrigation

TABLE H-25
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 256

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crops																	
Alfalfa	Border	-	5	917	0.13	0.09	0.04	0.41	0.54	0.63	0.65	0.65	0.49	0.24	0.14	0.03	4.04
Alfalfa	Border	-	10	947	-	-	-	-	-	-	-	-	-	-	-	-	4.20
Field Crops																	
Beans (dry)	Furrow	-	2	72	-	-	-	-	-	-	-	-	-	-	-	-	2.15
Beans (dry)	Linear-move sprinkler	-	1	144	-	-	-	-	-	-	-	-	-	-	-	-	1.80
Cotton	Furrow	-	26	3,881	0.06	0.27	0.51	0.02	0.04	0.62	0.84	0.74	0.02	0.00	0.00	0.00	3.12
Cotton	Furrow	-	87	4,723	-	-	-	-	-	-	-	-	-	-	-	-	2.36
Cotton	Linear-move sprinkler	-	3	1,070	0.00	0.00	0.22	0.05	0.00	0.37	0.87	0.76	0.00	0.00	0.00	0.00	2.27
Grain sorghum	Furrow	-	2	74	0.00	0.00	0.00	0.00	0.00	0.44	0.45	0.60	0.44	0.00	0.00	0.00	1.93
Grain sorghum	Furrow	-	1	39	-	-	-	-	-	-	-	-	-	-	-	-	3.04
Onions (seed)	Furrow	-	1	12	-	-	-	-	-	-	-	-	-	-	-	-	8.00
Soybeans	Furrow	-	2	113	0.00	0.00	0.00	0.00	0.00	0.89	0.25	0.66	0.52	0.00	0.00	0.00	2.32
Grains																	
Oat hay	Furrow	-	1	20	-	-	-	-	-	-	-	-	-	-	-	-	0.45
Wheat and barley	Border	-	6	326	0.28	0.02	0.24	0.29	0.13	0.00	0.00	0.00	0.00	0.04*	0.00	0.10*	1.10
Wheat and barley	Border	-	6	256	-	-	-	-	-	-	-	-	-	-	-	-	0.83
Wheat	Linear-move sprinkler	-	6	1,588	0.10	0.02	0.23	0.43	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31
Wheat	Linear-move sprinkler	-	5	1,095	-	-	-	-	-	-	-	-	-	-	-	-	1.60
Truck Crops																	
Asparagus	Furrow	-	2	573	0.00	0.19	0.24	0.58	0.81	0.82	1.45	1.41	0.69	0.05	0.00	0.00	6.24
Asparagus	Furrow	-	2	573	-	-	-	-	-	-	-	-	-	-	-	-	7.10
Beans (green)	Sprinkler	-	1	144	-	-	-	-	-	-	-	-	-	-	-	-	1.40
Flowers and nursery	Furrow	-	155	6,000	0.07	0.12	0.23	0.30	0.41	0.50	0.50	0.51	0.38	0.44	0.19	0.14	3.79
Onions	Furrow	-	2	352	0.03	0.01	0.17	0.43	0.62	0.17	0.00	0.00	0.00	0.00	0.00	2.07*	3.50
Potatoes	Sprinkler	-	3	347	0.00	0.00	0.09	0.59	0.67	0.47	0.06	0.00	0.00	0.00	0.00	1.46*	3.34
Potatoes	Linear-move sprinkler	-	2	434	-	-	-	-	-	-	-	-	-	-	-	-	2.10
Deciduous Orchard																	
Almonds	Border	1-3 yrs	7	980	0.02	0.07	0.26	0.17	0.28	0.45	0.32	0.28	0.23	0.47	0.00	0.00	2.55
Almonds	Border	4-7 yrs	13	2,029	0.06	0.36	0.08	0.35	0.53	0.66	0.52	0.14	0.18	0.32	0.00	0.00	3.20
Almonds	Border	8+ yrs	6	1,425	0.16	0.48	0.17	0.53	0.64	0.69	0.84	0.24	0.22	0.38	0.00	0.00	4.35
Almonds	Border	1-3 yrs	3	55	-	-	-	-	-	-	-	-	-	-	-	-	2.65
Almonds	Border	4-7 yrs	23	930	-	-	-	-	-	-	-	-	-	-	-	-	2.76
Almonds	Border	8+ yrs	17	762	-	-	-	-	-	-	-	-	-	-	-	-	3.48
Almonds	Sprinkler	4-7 yrs	6	2,070	0.02	0.06	0.09	0.16	0.52	0.42	0.45	0.31	0.19	0.22	0.03	0.04	2.51
Almonds	Sprinkler	8+ yrs	61	10,091	0.02	0.17	0.09	0.27	0.38	0.53	0.59	0.23	0.12	0.27	0.09	0.03	2.79
Almonds	Drip	1-3 yrs	6	2,323	0.00	0.01	0.02	0.07	0.13	0.10	0.19	0.14	0.11	0.07	0.02	0.01	0.87
Almonds	Drip	4-7 yrs	16	9,761	0.01	0.03	0.05	0.15	0.25	0.36	0.46	0.21	0.23	0.13	0.08	0.00	1.96
Almonds	Drip	8+ yrs	26	3,545	0.02	0.04	0.15	0.28	0.43	0.52	0.55	0.25	0.21	0.20	0.07	0.03	2.75
Apricots	Drip	4-7 yrs	1	36	0.00	0.04	0.24	0.32	0.26	0.43	0.36	0.42	0.13	0.11	0.00	0.00	2.31
Apricots	Drip	8+ yrs	2	49	0.10	0.17	0.20	0.55	0.56	0.46	0.51	0.51	0.23	0.26	0.03	0.00	3.58
Peaches & nectarines	Drip	4-7 yrs	3	298	0.00	0.03	0.13	0.23	0.20	0.37	0.32	0.38	0.10	0.03	0.00	0.00	1.79
Peaches & nectarines	Drip	8+ yrs	36	1,907	0.02	0.12	0.18	0.29	0.63	0.44	0.56	0.52	0.12	0.08	0.03	0.00	2.99
Peaches & nectarines	Border	4-7 yrs	1	166	0.00	0.20	0.00	0.69	1.05	0.72	1.80	0.56	0.77	0.00	0.00	0.00	5.79
Peaches & nectarines	Border	4-7 yrs	1	166	-	-	-	-	-	-	-	-	-	-	-	-	6.10
Pistachios	Furrow	9-12 yrs	2	94	0.00	0.00	0.16	0.14	0.36	0.21	0.58	0.92	0.19	0.46	0.00	0.00	3.02
Pistachios	Furrow	13+ yrs	1	47	0.00	0.35	0.00	0.22	0.53	0.53	0.60	0.58	0.64	0.45	0.00	0.00	3.90
Pistachios	Sprinkler	5-8 yrs	2	649	0.00	0.00	0.33	0.09	0.50	0.38	0.53	0.59	0.31	0.37	0.00	0.07	3.17
Pistachios	Sprinkler	9-12 yrs	2	298	0.00	0.00	0.04	0.10	0.16	0.30	0.36	0.40	0.04	0.00	0.00	0.00	1.40
Pistachios	Sprinkler	13+ yrs	3	1,957	0.03	0.04	0.05	0.25	0.37	0.39	0.44	0.58	0.15	0.13	0.09	0.11	2.63
Pistachios	Drip	5-8 yrs	6	1,017	0.00	0.00	0.05	0.07	0.13	0.23	0.19	0.23	0.03	0.00	0.00	0.00	0.93
Pistachios	Drip	9-12 yrs	14	2,513	0.00	0.04	0.06	0.15	0.26	0.39	0.44	0.45	0.01	0.01	0.02	0.00	1.83
Subtropical Orchard																	
Avocado	8+ yrs	Drip	1	13	0.00	0.00	0.00	0.06	0.21	0.20	0.20	0.30	0.20	0.23	0.05	0.00	1.45
Citrus	Sprinkler	1-3 yrs	2	197	0.00	0.08	0.00	0.17	0.26	0.20	0.53	0.36	0.16	0.00	0.00	0.00	1.76
Citrus	Sprinkler	4-7 yrs	2	646	0.00	0.09	0.04	0.12	0.14	0.27	0.49	0.22	0.07	0.34	0.15	0.18	2.11
Citrus	Sprinkler	8+ yrs	11	4,702	0.03	0.04	0.08	0.16	0.25	0.45	0.46	0.43	0.31	0.30	0.16	0.10	2.77
Citrus	Drip	4-7 yrs	2	299	0.00	0.02	0.03	0.09	0.09	0.17	0.20	0.19	0.07	0.08	0.02	0.04	1.00
Citrus	Drip	8+ yrs	41	3,621	0.04	0.03	0.09	0.17	0.31	0.35	0.39	0.41	0.23	0.23	0.11	0.05	2.41
Kiwi	Drip	4+ yrs	2	12	0.00	0.00	0.14	0.10	0.16	0.23	0.32	0.21	0.40	0.24	0.00	0.11	1.91
Olives	Sprinkler	8+ yrs	3	561	0.05	0.10	0.08	0.36	0.26	0.20	0.46	0.40	0.54	0.21	0.12	0.00	2.78
Olives	Drip	8+ yrs	10	1,135	0.00	0.03	0.08	0.17	0.27	0.30	0.29	0.50	0.41	0.12	0.00	0.00	2.17
Vineyard																	
Grapes	Border	3+ yrs	20	959	-	-	-	-	-	-	-	-	-	-	-	-	2.38
Grapes	Border	3+ yrs	1	535	0.00	0.00	0.00	1.06	0.28	1.10	0.78	0.00	0.00	0.85	0.36	0.00	4.43
Grapes	Sprinkler	3+ yrs	8	428	0.00	0.00	0.16	0.22	0.44	0.53	0.54	0.41	0.10	0.19	0.06	0.00	2.65
Grapes	Drip	1-2 yrs	3	537	0.03	0.22	0.06	0.15	0.18	0.18	0.02	0.22	0.12	0.02	0.02	0.00	1.22
Grapes	Drip	3+ yrs	45	4,250	0.03	0.08	0.11	0.22	0.30	0.44	0.43	0.39	0.08	0.01	0.03	0.00	2.12

*Preirrigation

TABLE H-26
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 258

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Forage Crops																	
Alfalfa	Border	-	1	158	0.28	0.25	0.00	0.54	0.46	0.48	0.38	0.51	0.39	0.56	0.04	0.00	3.89
Field Crops																	
Castor beans	Furrow	-	1	80	-	-	0.42	0.00	-	0.96	0.63	0.33	0.33	-	-	-	2.67
Cotton	Sprinkler	-	1	151	1.23	0.23	-	-	-	0.38	0.62	0.25	-	-	-	-	2.71
Cotton	Furrow	-	4	686	-	0.06	0.23	0.22	0.25	0.47	0.84	0.87	0.24	0.02	-	-	3.20
Sugar beets	Sprinkler	-	1	156	0.01	0.03	0.13	0.44	0.49	0.81	0.53	-	-	-	-	-	2.44
Grains																	
Wheat	Border	-	1	39	-	-	0.59	0.18	0.13	-	-	-	-	-	-	-	0.90
Truck Crops																	
Carrots	Sprinkler	-	2	279	-	-	-	0.07	0.10	0.18	0.48	0.38	0.30	0.08	0.13	-	1.72
Melons	Furrow	-	1	80	1.00	-	-	0.33	0.33	0.67	-	-	-	-	-	-	2.33
Melons	Furrow	-	2	120	-	-	-	-	-	-	-	-	-	-	-	-	2.35
Potatoes	Sprinkler	-	10	1,498	0.01	0.06	0.36	0.64	0.29	0.16	0.07	-	-	-	0.26*	0.02*	1.87
Tomatoes (processing)	Furrow	-	2	234	0.22	0.25	0.11	0.00	0.68	0.88	0.37	-	-	-	0.00	0.00	2.51
Tomatoes (processing)	Furrow	-	1	80	-	-	-	-	-	-	-	-	-	-	-	-	2.46
Deciduous Orchard																	
Almonds	Sprinkler	8+ yrs	1	304	0.10	0.03	0.00	0.45	0.45	0.61	0.64	0.43	0.29	0.00	0.49	0.00	3.49
Subtropical Orchard																	
Citrus	Mister	1-3 yrs	1	76	-	-	-	-	0.08	0.12	0.13	0.22	0.13	0.24	0.05	0.05	1.02
Citrus	Sprinkler	4-7 yrs	1	133	-	0.22	-	0.30	0.54	0.60	0.44	0.74	0.51	0.20	0.18	0.00	3.73
Citrus	Sprinkler	8+ yrs	5	1,108	0.01	0.01	0.06	0.20	0.32	0.33	0.55	0.45	0.46	0.38	0.09	0.07	2.93
Citrus	Furrow	8+ yrs	1	257	-	-	-	0.39	0.43	0.51	0.49	0.48	0.45	0.29	0.08	-	3.12
Jojoba	Drip	-	1	304	-	-	-	0.13	0.18	0.38	0.34	0.28	0.32	0.59	0.00	-	2.22
Vineyard																	
Grapes	Furrow	3+ yrs	12	3,438	0.01	0.12	0.20	0.43	0.43	0.62	0.63	0.30	0.12	0.19	0.05	0.07	3.17
Grapes	Sprinkler	1-2 yrs	2	298	0.01	0.21	0.19	0.33	0.46	0.69	0.69	0.41	0.35	0.00	0.00	0.13	3.47
Grapes	Sprinkler	3+ yrs	15	2,662	0.16	0.30	0.05	0.23	0.27	0.61	0.75	0.36	0.17	0.24	0.00	0.06	3.20

*Preirrigation

TABLE H-27
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 259

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Beans (dry)	Sprinkler	–	2	340	–	–	–	–	–	–	–	–	–	–	–	–	1.67
Cotton	Sprinkler	–	29	14,497	0.01	0.20	0.38	0.10	0.27	0.55	1.02	1.04	0.01	0.00	0.00	0.00	3.58
Cotton	Sprinkler	–	2	2.350	–	–	–	–	–	–	–	–	–	–	–	–	3.34
Sugar beets	Sprinkler	–	4	11,251	0.03	0.05	0.28	0.38	0.67	0.91	1.06	1.12	0.83	0.26	0.00	0.00	5.59
Grains																	
Wheat and barley	Sprinkler	–	6	5,085	0.24	0.23	0.31	0.66	0.28	0.03	0.00	0.00	0.00	0.00	0.00	0.04	1.79
Wheat and barley	Sprinkler	–	3	3.727	–	–	–	–	–	–	–	–	–	–	–	–	1.74
Truck Crops																	
Broccoli	Sprinkler	–	1	100	–	–	–	–	–	–	–	–	–	–	–	–	1.78
Carrots	Sprinkler	–	2	660	–	–	–	–	–	–	–	–	–	–	–	–	2.13
Lettuce (spring)	Furrow	–	5	1,400	0.11	0.25	0.37	0.26	0.00	0.00	0.00	0.00	0.00	0.11*	0.01*	0.24*	1.35
Lettuce (fall)	Furrow	–	6	2,100	0.00	0.00	0.00	0.00	0.00	0.11	0.19	0.62	0.63	0.24	0.01	0.00	1.80
Melons	Furrow	–	7	2,210	0.24	0.27	0.14	0.05	0.25	0.64	0.52	0.02	0.00	0.00	0.00	0.00	2.13
Onions and garlic	Sprinkler	–	10	3,147	0.17	0.21	0.25	0.52	0.65	0.40	0.07	0.12	0.02	0.06	0.30	0.17	2.94
Onions and garlic	Sprinkler	–	5	1,841	–	–	–	–	–	–	–	–	–	–	–	–	3.06
Peas	Sprinkler	–	2	585	–	–	–	–	–	–	–	–	–	–	–	–	1.92
Peppers	Sprinkler	–	1	96	0.00	0.00	0.04	0.87	1.19	0.43	1.46	1.83	0.58	0.00	0.00	0.00	6.40
Peppers	Sprinkler	–	1	95	–	–	–	–	–	–	–	–	–	–	–	–	3.00
Potatoes	Sprinkler	–	3	578	0.00	0.06	0.09	0.29	0.77	0.57	0.11	0.00	0.00	0.00	0.00	0.00	1.89
Spinach	Sprinkler	–	1	220	–	–	–	–	–	–	–	–	–	–	–	–	1.89
Tomatoes (processing)	Furrow	–	2	331	0.42	0.02	0.06	0.03	0.47	0.75	0.50	0.02	0.00	0.00	0.00	0.00	2.27
Tomatoes (processing)	Furrow	–	1	140	–	–	–	–	–	–	–	–	–	–	–	–	2.51
Deciduous Orchard																	
Almonds	Drip	1-3 yrs	1	80	0.09	0.00	0.20	0.00	0.09	0.06	0.30	0.49	0.00	0.00	0.00	0.00	1.23
Almonds	Drip	4-7 yrs	4	320	0.08	0.12	0.07	0.25	0.33	0.39	0.43	0.28	0.11	0.15	0.11	0.05	2.37
Almonds	Drip	8+ yrs	1	80	0.11	0.29	0.19	0.34	0.51	0.69	0.70	0.41	0.24	0.28	0.13	0.18	4.07
Almonds	Sprinkler	1-3 yrs	16	8,296	0.05	0.19	0.23	0.33	0.35	0.55	0.52	0.43	0.14	0.17	0.04	0.11	3.11
Almonds	Sprinkler	4-7 yrs	45	7,994	0.03	0.19	0.24	0.34	0.56	0.67	0.72	0.42	0.06	0.04	0.05	0.06	3.38
Almonds	Sprinkler	8+ yrs	36	20,131	0.10	0.06	0.17	0.40	0.51	0.62	0.63	0.27	0.08	0.30	0.11	0.23	3.48
Almonds	Sprinkler	8+ yrs	33	18,529	–	–	–	–	–	–	–	–	–	–	–	–	4.63
Almonds	Hose-pull	1-3 yrs	29	7,829	0.03	0.09	0.11	0.22	0.27	0.30	0.29	0.25	0.18	0.09	0.05	0.04	1.92
Almonds	Hose-pull	4-7 yrs	32	18,503	0.16	0.09	0.17	0.33	0.41	0.47	0.46	0.25	0.12	0.20	0.07	0.12	2.85
Almonds	Hose-pull	8+ yrs	8	764	0.21	0.14	0.28	0.47	0.63	0.92	0.50	0.09	0.14	0.21	0.03	0.11	3.73
Apricots	Sprinkler	1-3 yrs	1	89	0.00	0.16	0.27	0.45	0.30	0.30	0.30	0.28	0.17	0.24	0.01	0.00	2.48
Peaches & nectarines	Drip	4-7 yrs	6	230	0.15	0.08	0.30	0.24	0.36	0.36	0.35	0.42	0.35	0.18	0.02	0.08	2.89
Peaches & nectarines	Hose-pull	1-3 yrs	27	2,853	0.09	0.14	0.18	0.21	0.33	0.33	0.31	0.26	0.26	0.14	0.06	0.05	2.36
Peaches & nectarines	Hose-pull	4-7 yrs	25	913	0.12	0.11	0.26	0.42	0.50	0.52	0.32	0.35	0.32	0.20	0.04	0.11	3.27
Peaches & nectarines	Hose-pull	8+ yrs	6	176	0.22	0.00	0.29	0.27	0.46	0.54	0.36	0.46	0.52	0.00	0.00	0.22	3.34
Peaches & nectarines	Furrow	1-3 yrs	3	30	0.10	0.11	0.27	0.50	0.58	0.35	0.29	0.24	0.27	0.09	0.00	0.00	2.80
Peaches & nectarines	Furrow	4-7 yrs	1	10	0.44	0.53	0.80	1.59	0.35	0.66	0.88	0.88	0.44	0.44	0.00	0.00	7.01
Pecans	Sprinkler	1-3 yrs	1	50	–	–	–	–	–	–	–	–	–	–	–	–	2.66
Pistachios	Hose-pull	1-4 yrs	2	22	0.00	0.16	0.24	0.32	0.32	0.64	0.36	0.59	0.48	0.24	0.00	0.00	3.35
Pistachios	Hose-pull	5-8 yrs	4	44	0.00	0.10	0.12	0.28	0.46	0.48	0.50	0.35	0.24	0.08	0.02	0.17	2.80
Pistachios	Hose-pull	9-12 yrs	4	1,844	0.04	0.00	0.09	0.29	0.34	0.35	0.47	0.48	0.03	0.17	0.15	0.13	2.54
Pistachios	Drip	1-4 yrs	28	10,404	0.03	0.10	0.20	0.17	0.19	0.26	0.27	0.22	0.03	0.01	0.00	0.01	1.49
Pistachios	Drip	5-8 yrs	27	18,907	0.02	0.02	0.05	0.12	0.17	0.23	0.24	0.24	0.06	0.09	0.06	0.07	1.37
Pistachios	Drip	1-4 yrs	1	812	–	–	–	–	–	–	–	–	–	–	–	–	0.45
Pistachios	Drip	5-8 yrs	34	6,958	–	–	–	–	–	–	–	–	–	–	–	–	1.60
Plums	Hose-pull	1-3 yrs	6	492	0.06	0.14	0.19	0.21	0.43	0.43	0.48	0.30	0.41	0.20	0.12	0.00	2.97
Plums	Hose-pull	4-7 yrs	7	669	0.16	0.19	0.29	0.33	0.50	0.48	0.40	0.39	0.41	0.21	0.02	0.00	3.38
Plums	Hose-pull	8+ yrs	6	636	0.07	0.14	0.20	0.33	0.46	0.50	0.40	0.30	0.45	0.17	0.02	0.09	3.13
Subtropical Orchard																	
Citrus	Drip	4-7 yrs	6	251	0.01	0.04	0.06	0.10	0.15	0.16	0.17	0.39	0.21	0.14	0.08	0.00	1.51
Citrus	Drip	8+ yrs	8	168	0.01	0.03	0.06	0.15	0.14	0.28	0.39	0.89	0.21	0.32	0.05	0.10	2.63
Citrus	Sprinkler	1-3 yrs	3	769	0.00	0.00	0.15	0.14	0.40	0.38	0.39	0.30	0.34	0.17	0.11	0.00	2.38
Citrus	Hose-pull	1-3 yrs	39	4,743	0.00	0.07	0.11	0.18	0.31	0.27	0.23	0.28	0.17	0.19	0.06	0.00	1.87
Citrus	Hose-pull	4-7 yrs	47	6,147	0.02	0.08	0.13	0.20	0.30	0.33	0.32	0.36	0.32	0.19	0.10	0.01	2.36
Citrus	Hose-pull	8+ yrs	17	2,706	0.02	0.08	0.08	0.19	0.44	0.54	0.45	0.49	0.37	0.24	0.16	0.04	3.10
Olives	Hose-pull	1-3 yrs	8	1,161	0.01	0.07	0.09	0.09	0.20	0.22	0.25	0.22	0.12	0.14	0.10	0.00	1.51
Olives	Hose-pull	4-7 yrs	21	3,009	0.00	0.15	0.22	0.28	0.34	0.36	0.40	0.38	0.29	0.11	0.05	0.05	2.63
Olives	Hose-pull	8+ yrs	16	2,175	0.01	0.10	0.13	0.27	0.38	0.45	0.45	0.41	0.21	0.12	0.16	0.19	2.88
Vineyard																	
Grapes	Drip	1-2 yrs	2	144	0.00	0.00	0.02	0.02	0.02	0.19	0.16	0.14	0.05	0.00	0.02	0.00	0.62
Grapes	Sprinkler	1-2 yrs	2	800	0.53	0.60	0.20	0.02	0.20	0.51	0.64	0.23	0.00	0.00	0.00	0.00	2.93
Grapes	Sprinkler	3+ yrs	12	19,458	0.05	0.02	0.05	0.15	0.25	0.38	0.50	0.39	0.17	0.15	0.04	0.15	2.30
Grapes	Furrow	1-2 yrs	3	190	0.00	0.18	0.04	0.66	0.54	0.94	0.32	0.15	0.10	0.08	0.06	0.00	3.07
Grapes	Furrow	3+ yrs	1	70	0.00	0.00	1.25	0.59	0.43	0.48	0.35	0.04	0.22	0.00	0.00	0.00	3.36

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*Preirrigation

TABLE H-28
AVERAGE MEASURED IRRIGATION DELIVERIES
TULARE LAKE HSA
DAU 261

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Beans (dry)	Furrow	-	1	151	-	-	-	-	0.42	0.26	0.32	0.17	0.21	-	-	-	1.38
Beans (dry)	Sprinkler	-	1	220	-	-	-	-	-	-	-	-	-	-	-	-	2.23
Cotton	Sprinkler	-	110	25,968	0.02	0.09	0.21	0.09	0.12	0.51	0.77	0.77	0.08	-	-	-	2.66
Cotton	Sprinkler	-	4	538	-	-	-	-	-	-	-	-	-	-	-	-	2.89
Sugar beets	Sprinkler	-	5	639	-	0.02	0.28	0.22	0.56	0.89	0.60	0.28	-	-	-	-	2.85
Grains																	
Wheat	Sprinkler	-	1	253	-	-	-	-	-	-	-	-	-	-	-	-	2.13
Truck Crops																	
Melons	Furrow	-	12	2,019	-	-	-	0.09	0.52	0.76	0.61	0.33	-	-	-	-	2.31
Potatoes	Sprinkler	-	1	206	-	-	-	-	-	-	-	-	-	-	-	-	2.69
Tomatoes (processing)	Furrow	-	2	305	-	0.08	0.03	0.13	0.66	0.76	0.35	0.18	0.02	0.00	-	-	2.21
Deciduous Orchard																	
Peaches & nectarines	Sprinkler	8+ yrs	2	452	-	-	0.03	0.29	0.59	0.48	0.65	0.57	0.37	0.36	0.21	-	3.55
Peaches & nectarines	Sprinkler	8+ yrs	6	1,027	-	-	-	-	-	-	-	-	-	-	-	-	3.12
Plums	Sprinkler	8+ yrs	4	754	0.01	0.01	-	0.23	0.38	0.45	0.37	0.52	0.31	0.34	0.09	0.06	2.77
Subtropical Orchard																	
Citrus	Sprinkler	8+ yrs	19	5,761	0.02	0.01	0.00	0.16	0.20	0.38	0.41	0.52	0.34	0.22	0.18	0.02	2.46
Citrus	Sprinkler	8+ yrs	15	2,337	-	-	-	-	-	-	-	-	-	-	-	-	2.50
Vineyard																	
Grapes	Sprinkler	3+ yrs	7	1,651	0.00	0.02	0.07	0.22	0.28	0.41	0.45	0.58	0.32	0.13	0.09	0.06	2.63
Grapes	Sprinkler	3+ yrs	5	1,384	-	-	-	-	-	-	-	-	-	-	-	-	2.77

TABLE H-29
AVERAGE MEASURED IRRIGATION DELIVERIES
SOUTH LAHONTAN HSA
DAU 306

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI-GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crop																	
Sugar beets	Sprinkler	-	2	390	-	-	-	-	-	-	-	-	-	-	-	-	5.1
Forge Crops																	
Alfalfa	Sprinkler	-	7	1,040	-	-	-	-	-	-	-	-	-	-	-	-	5.1
Truck Crops																	
Onions	Sprinkler	-	1	110	-	-	-	-	-	-	-	-	-	-	-	-	3.9

TABLE H-30
AVERAGE MEASURED IRRIGATION DELIVERIES
COLORADO RIVER HSA
DAU 345

CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Cotton	Furrow	–	4	228	–	–	0.4	0.6	0.2	0.7	1.8	1.0	0.6	0.1	–	–	5.4
Milo	Furrow	–	4	189	–	–	–	–	0.3	0.8	1.2	1.0	0.5	0.1	–	–	3.9
Forage																	
Alfalfa	Border	–	3	112	0.2	0.3	0.4	0.8	0.8	1.0	0.7	0.7	0.6	0.4	0.1	0.0	6.0
Grains																	
Barley	Flood	–	3	150	0.4	0.5	0.6	0.6	–	–	–	–	–	–	–	–	2.1
Truck Crops																	
Cantaloupes	Furrow	–	4	139	–	–	1.0	0.7	0.9	0.6	–	–	–	–	–	–	3.2
Lettuce	Furrow	–	4	131	0.3	0.2	0.1	–	–	–	–	– [a]	0.8[b]	0.3	0.8	0.3	2.8
Onions	Furrow	–	4	121	0.4	0.4	0.3	0.6	0.6	–	–	–	–	–	–	0.3[b]	2.6

[a] Includes preirrigation and leaching water.
[b] Start of growing season.

TABLE H-31
AVERAGE MEASURED IRRIGATION DELIVERIES
COLORADO RIVER HSA
DAU 353

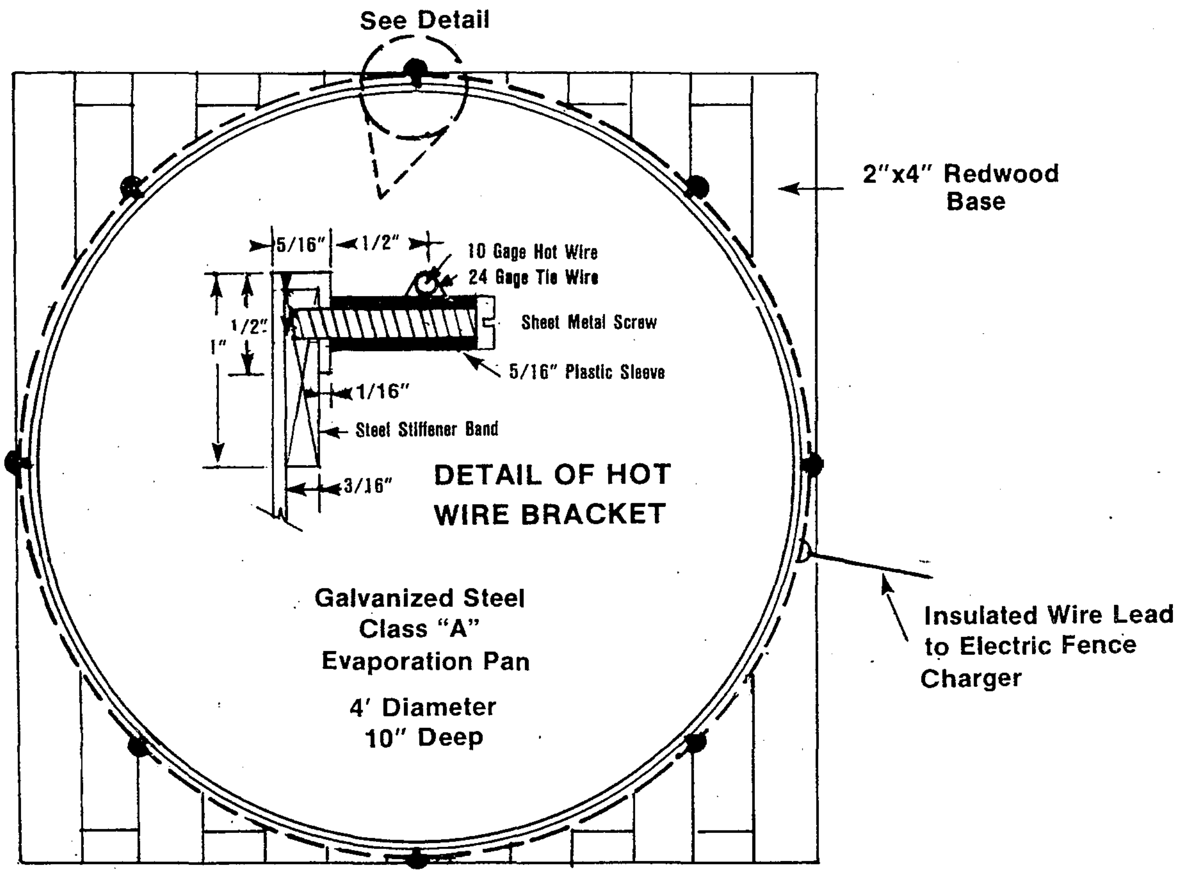
CROP	IRRIGATION METHOD	AGE (TREES/ VINES)	NO. OF FIELDS	ACRES IRRI- GATED	AVERAGE MEASURED MONTHLY AND ANNUAL DELIVERIES (ACRE-FEET/ACRE)												
					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Field Crops																	
Cotton	Furrow	–	4	470	T	0.1	0.5	0.2	0.4	0.6	1.0	0.8	0.6	0.1	–	0.1[a]	4.4[b] [c]
Cotton	Furrow	–	15	1,605	–	–	0.3	0.4	0.2	0.8	0.9	0.7	0.6	–	–	–	3.9
Sugar Beets	Furrow	–	7	830	0.3	0.3	0.5	0.6	0.5	T	0.4[a]	0.2	0.5	0.4	0.2	0.3	4.2[c]
Forage Crops																	
Alfalfa	Border	–	8	835	0.2	0.3	0.6	0.8	0.9	0.8	1.0	0.8	0.7	0.5	0.5	0.2	7.3[b] [c]
Alfalfa	Border	–	15	1,469	0.1	0.4	0.3	0.7	0.7	0.9	0.8	0.6	0.5	0.4	0.2	0.1	5.7
Bermuda Grass	Flood	–	1	158	–	–	–	–	–	–	0.2[a]	0.9	0.6	0.2	0.0	0.0	–
Bermuda Grass	Flood	–	1	158	0.0	0.0	0.1	0.3	0.3	0.1	0.0	0.4	0.3	0.3	0.0	0.0	1.8[b] [c]
Sudan	Flood	–	1	64	–	–	–	–	–	0.9	0.9	1.3	–	–	–	–	3.1[b] [c]
Grains																	
Barley	Flood	–	1	158	0.2	0.0	0.4	0.5	–	–	–	–	–	–	–	0.4[a]	1.5[b] [c]
Wheat	Flood	–	9	1,197	0.2	0.4	0.9	0.3	0.1	–	–	T[d]	0.1[d]	–	–	0.3[a]	2.3[b] [c]
Wheat	Flood	–	13	1,172	0.3	0.3	0.4	0.5	T	–	–	–	–	T	0.1	T	1.6
Sorghum	Furrow	–	1	151	–	–	0.4	0.3	1.2	1.4	0.3	0.0	0.7	0.4	–	–	4.7[b] [c]
Truck																	
Asparagus	Furrow	–	1	34	0.0	0.0	0.4	0.5	0.8	0.4	0.2	0.2	0.0	0.0	0.0	0.0	2.5
Cantaloupes	Furrow	–	1	131	–	–	–	–	–	0.4	0.0	0.6	0.5	0.2	0.0	–	1.7[b] [c]
Lettuce	Furrow	–	3	308	0.2	0.1	–	–	–	–	–	0.3[a]	0.0	0.9	0.3	0.1	1.9[b] [c]

T = Trace (less than 0.05).

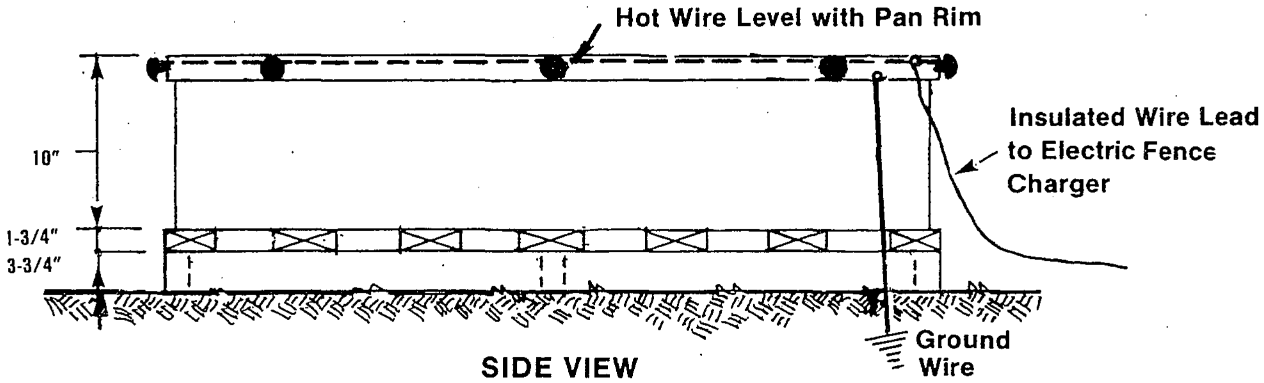
[a] New crop startup.
[b] Includes preirrigation but not leaching fraction.
[c] Funding for data collection provided by Imperial Irrigation District. Individuals and agencies obtaining this data were: Dr. L. Hermsmeir and M. Kaddah with the U. S. Department of Agriculture, Agricultural Research Service; and J. Meyer and D. Munson with the University of California Cooperative Extension, Riverside.
[d] For leaching only.

APPENDIX I

CLASS "A" PAN HOT-WIRE BIRD REPELLER



TOP VIEW



SIDE VIEW

FIGURE I-1. CONSTRUCTION DETAILS FOR CLASS "A" EVAPORATION PAN HOT-WIRE BIRD REPELLER

APPENDIX I. CLASS "A" PAN HOT-WIRE BIRD REPELLER

The standard operating criteria for Class "A" evaporation pans requires that the water level be maintained between 2 and 3 inches below the pan rim. A problem at a few evaporation stations is the number of birds that can reach into the pan and drink the water. Dryland pan sites are particularly attractive to birds during midsummer.

An index, of sorts, to the extent of the problem at Class "A" pan sites is the quantity of bird droppings found on the platform supporting the pan and the rate at which the droppings reappear after removal with a wire brush. A second problem that may be found at some dryland stations is caused by rodents, e.g., squirrels, which also can drink from the pans.

To counter the problem, DWR designed and installed a hot-wire bird "repeller" at two Class-"A" pan stations on dryland ranges, one in the hot northern Sacramento Valley and the other in a warm valley of the Coast Range. Both sites appeared to be attracting large numbers of birds, judging from the droppings found on the wooden pan support. After installation of the hot wire, the droppings essentially disappeared.

The hot wire (Figure I-1) is activated by a standard battery-operated fence electrification unit. Installation is quite simple. The hot wire is attached to insulated sheet metal screws, which have been inserted into the steel stiffener band surrounding the top edge of the pan.

To insulate the screws, the installer snips off the pointed tips of eight No. 6 x 5/8 sheet metal screws; these will be installed in shallow holes to be predrilled in the stiffener band. Before inserting the screws, the installer slips a short length of 5/16-inch plastic tubing over each screw, thus insulating the threads. As shown in Figure I-1, the insulated screws are inserted into the stiffener band about 18 inches apart.

The hot wire consists of a No. 10 gage galvanized wire loop, which is attached to the screws with No. 24 gage galvanized wire; the wire is wound several times around both the hot wire and the threaded (and insulated) portion of each screw protruding from the stiffener band. The hot wire is then connected to the charger unit, which is located about 10 feet from the pan. A ground wire is attached to the stiffener band as shown in Figure I-1.

To test the unit, the test operator places the tip of a blade of green grass on top of the hot wire while holding on to the blunt end. The operator then slides the blade forward slowly, thus shortening the distance between his fingers and the hot wire. If the unit is operating properly, the operator will feel a mild tingling sensation, which will increase as the strength of the current passing through the blade of grass increases.

Wire screening has also been used to deter birds and rodents, although screening will reduce the evaporation rate. On the Young evaporation pan, screening is standard equipment. The Young pan, which is 2 feet in diameter and 3 feet deep, is installed at ground level and covered with 1/4-inch wire mesh to reduce the evaporation rate to that of lake evaporation.

Chicken wire has also been used at some installations to keep birds and animals from drinking from the pan. Whereas chicken wire placed across the pan rim will not reduce the evaporation rate to the same degree as will 1/4-inch wire mesh, most birds will be able to drink from the pan when the water level is kept at the standard 2-inch freeboard (distance from the top of the pan to the water). Other types of chicken wire covers have been used recently by some researchers; whereas these new designs may prove to be practical, insufficient performance data are available at present.

APPENDIX J

RATIOS FOR ADJUSTING PAN EVAPORATION AND ETo-CIMIS TO CROP ET; CROP ET MEASUREMENTS; AND ET TEST PLOT ENVIRONMENTS

APPENDIX J

RATIOS FOR ADJUSTING PAN EVAPORATION AND ETo-CIMIS TO CROP ET; CROP ET MEASUREMENTS; AND ET TEST PLOT ENVIRONMENTS

Appendix J contains Kp and Kc ratios, Class "A" pan wind-humidity adjustment factors, and measured crop ET data. In addition, ET test-plot environments at Tulelake, Brawley, and Davis are shown. These subjects are discussed in Chapter III.

Table J-1 contains Kp ratios for adjusting measured evaporation from Class "A" pans operated in irrigated pasture and turfgrass to estimated weekly crop ET for the Central Valley of California. Table J-2 contains Class "A" pan adjustment factors that must be used to compensate for strong wind and humidity conditions before Kp ratios are applied.

Table J-3 shows Kc ratios for converting ETo-CIMIS to estimated crop ET in the Central Valley. Table J-4 contains crop ET lysimeter measurements from Tulelake, Brawley, and Davis; and neutron probe measurements from Wasco 8SW.

Vertical view layouts of the lysimeter test-plot environments for: (a) the University of California Tulelake Field Station are shown in Figure J-1; (b) the Agricultural Research Service Irrigated Desert Research Station at Brawley are shown in Figure J-2; and (c) the University of California, Davis are shown in Figure J-3.

Table J-1. Kp Ratios[1] (Coefficients) for Adjusting Evaporation from Class "A" Pans in Irrigated Pastures and Turfgrass to Estimate Weekly Crop Evapotranspiration for Several Crops in California's Central Valley (Redding to Bakersfield)

(Page 1 of 4)

Weekly	Pasture	Alfalfa[2] (Hay)	Olives	Deciduous Orchard				Sugar Beets[5]		
Period				Cover[3]	Clean Tilled[4]					
Ending	1/1-12/31	1/1-12/31	1/1-12/31	1/1-12/31	2/15-11/8	3/1-11/8	4/15-11/8	2/1-8/30	3/1-11/1	4/1-12/30
1/07	0.71	0.76		0.71						
1/14	0.71	0.76		0.71						
1/21	0.72	0.76		0.72						
1/28	0.73	0.76		0.73						
2/04	0.74	0.76		0.74				0.20		
2/11	0.74	0.76		0.75				0.20		
2/18	0.75	0.76		0.75	0.41			0.20		
2/25	0.75	0.76		0.75	0.44			0.20		
3/04	0.76	0.76		0.76	0.46	0.41		0.21	0.11	
3/11	0.76	0.76		0.78	0.49	0.44		0.22	0.13	
3/18	0.77	0.76		0.80	0.51	0.46		0.24	0.16	
3/25	0.77	0.76		0.81	0.53	0.49		0.27	0.22	
4/01	0.77	0.76		0.83	0.56	0.51		0.30	0.27	
4/08	0.77	0.76		0.84	0.58	0.53		0.36	0.32	0.11
4/15	0.78	0.76		0.86	0.60	0.56		0.43	0.38	0.13
4/22	0.78	0.76		0.87	0.63	0.58	0.41	0.54	0.43	0.16
4/29	0.78	0.76		0.89	0.65	0.60	0.44	0.68	0.65	0.22
5/06	0.78	0.76	0.50	0.90	0.67	0.63	0.46	0.78	0.77	0.27
5/13	0.78	0.76	0.50	0.91	0.68	0.65	0.49	0.85	0.84	0.32
5/20	0.78	0.76	0.50	0.92	0.69	0.67	0.51	0.88	0.88	0.38
5/27	0.78	0.76	0.50	0.93	0.71	0.68	0.53	0.91	0.90	0.43
6/03	0.78	0.76	0.50	0.93	0.73	0.69	0.56	0.91	0.91	0.65
6/10	0.78	0.76	0.50	0.94	0.74	0.71	0.58	0.91	0.91	0.77
6/17	0.78	0.76	0.50	0.94	0.75	0.73	0.60	0.91	0.91	0.84
6/24	0.78	0.76	0.50	0.94	0.75	0.74	0.63	0.92	0.91	0.88
7/01	0.78	0.76	0.50	0.94	0.75	0.75	0.65	0.92	0.92	0.90
7/08	0.78	0.76	0.50	0.94	0.75	0.75	0.67	0.91	0.92	0.91
7/15	0.78	0.76	0.50	0.95	0.75	0.75	0.68	0.91	0.92	0.91
7/22	0.78	0.76	0.50	0.95	0.75	0.75	0.69	0.91	0.92	0.91
7/29	0.78	0.76	0.50	0.94	0.75	0.75	0.71	0.91	0.92	0.91
8/05	0.78	0.76	0.50	0.94	0.75	0.75	0.73	0.90	0.92	0.92
8/12	0.78	0.76	0.50	0.94	0.74	0.75	0.74	0.88	0.92	0.92
8/19	0.78	0.76	0.50	0.93	0.74	0.75	0.75	0.84	0.92	0.92
8/26	0.78	0.76	0.50	0.92	0.72	0.75	0.75	0.81	0.92	0.92
9/02	0.78	0.76	0.50	0.91	0.70	0.74	0.75		0.92	0.92
9/09	0.78	0.76		0.90	0.67	0.72	0.75		0.91	0.92
9/16	0.78	0.76		0.89	0.65	0.70	0.75		0.89	0.92
9/23	0.77	0.76		0.88	0.62	0.67	0.75		0.87	0.92
9/30	0.77	0.76		0.86	0.59	0.65	0.75		0.86	0.92
10/07	0.77	0.76		0.84	0.56	0.62	0.75		0.85	0.92
10/14	0.76	0.76		0.83	0.52	0.59	0.75		0.84	0.92
10/21	0.75	0.76		0.80	0.47	0.56	0.74		0.84	0.92
10/28	0.75	0.76		0.80	0.43	0.52	0.72		0.84	0.92
11/04	0.75	0.76		0.78	0.40	0.47	0.70			0.92
11/11	0.74	0.76		0.76			0.67			0.91
11/18	0.73	0.76		0.74						0.89
11/25	0.73	0.76		0.73						0.87
12/02	0.72	0.76		0.72						0.86
12/09	0.71	0.76		0.71						0.85
12/16	0.71	0.76		0.71						0.84
12/23	0.70	0.76		0.70						0.84
12/30	0.70	0.76		0.70						0.84

NOTE: All footnotes are on page 2 (of 4).

Table J-1. Kp Ratios[1] (Coefficients)
For Adjusting Evaporation from Class A Pans
In Irrigated Pastures and Turfgrass to Estimate Weekly Crop Evapotranspiration
for Several Crops in California's Central Valley (Redding to Bakersfield)

(Page 2 of 4)

Weekly Period Ending	Table Grapes[4]			Corn[5]			Dry Beans (Pinto)[5]		Rice[6]	
	3/1-11/8	3/15-11/8	4/15-11/8	4/1-8/26	5/1-9/12	6/15-10/19	5/1-8/21	6/1-9/21	4/15-9/19	5/15-10/9
3/4	0.10									
3/11	0.11									
3/18	0.13	0.10								
3/25	0.18	0.11								
4/01	0.32	0.13								
4/08	0.40	0.18		0.15						
4/15	0.46	0.32		0.16						
4/22	0.50	0.40	0.10	0.17					0.79	
4/29	0.54	0.46	0.11	0.20					0.80	
5/06	0.57	0.50	0.13	0.25	0.14		0.11		0.81	
5/13	0.60	0.54	0.18	0.33	0.15		0.11		0.81	
5/20	0.63	0.57	0.32	0.43	0.18		0.11		0.83	0.79
5/27	0.65	0.60	0.40	0.55	0.23		0.19		0.85	0.80
6/03	0.66	0.63	0.46	0.70	0.30		0.61	0.09	0.89	0.81
6/10	0.66	0.65	0.50	0.86	0.37		0.82	0.11	0.93	0.81
6/17	0.66	0.66	0.54	0.93	0.50	0.14	0.88	0.35	0.97	0.83
6/24	0.66	0.66	0.57	0.95	0.64	0.15	0.90	0.41	0.99	0.85
7/01	0.66	0.66	0.60	0.95	0.78	0.20	0.90	0.61	1.00	0.89
7/08	0.66	0.66	0.63	0.95	0.88	0.30	0.90	0.82	1.00	0.93
7/15	0.66	0.66	0.65	0.94	0.95	0.47	0.90	0.88	1.00	0.97
7/22	0.66	0.66	0.66	0.92	0.95	0.67	0.87	0.90	1.00	0.99
7/29	0.64	0.66	0.66	0.87	0.93	0.83	0.78	0.90	1.00	1.00
8/05	0.61	0.66	0.66	0.79	0.90	0.90	0.62	0.90	1.00	1.00
8/12	0.58	0.64	0.66	0.71	0.84	0.94	0.44	0.90	0.99	1.00
8/19	0.53	0.61	0.66	0.61	0.76	0.95	0.25	0.87	0.98	1.00
8/26	0.49	0.58	0.66	0.48	0.66	0.95		0.78	0.93	1.00
9/02	0.42	0.53	0.66		0.57	0.94		0.62	0.88	1.00
9/09	0.36	0.49	0.66		0.44	0.92		0.44	0.83	0.99
9/16	0.30	0.42	0.64			0.88		0.25		0.98
9/23	0.20	0.36	0.61			0.79				0.93
9/30	0.20	0.30	0.58			0.70				0.88
10/07	0.20	0.20	0.53			0.61				0.83
10/14	0.20	0.20	0.49			0.51				
10/21	0.20	0.20	0.42							
10/28	0.20	0.20	0.36							
11/04	0.20	0.20	0.30							
11/11			0.20							

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[1] Evaporation losses from a moist soil surface are very high for several days following each irrigation during plant emergence and establishment. These ratios do not account for this accelerated loss but do assume that soil moisture is not limiting plant growth.

[2] Alfalfa hay ratios are derived from total monthly ET. These ratios do not reflect the true weekly fluctuations in ET rates that occur continuously from mowing to full effective cover.

[3] Green all year due to cover crop.

[4] Average bloom and leaf-drop dates.

[5] Plant emergence and crop harvest or senescence dates.

[6] Continuously saturated soil. Ratio suitability for wild rice is not known.

Source: Elias Fereres-Castiel, University of California Extension Water Water Specialist, May 1977; and Department of Water Resources, September 1980.

Table J-1. Kp Ratios [1] (Coefficients)
For Adjusting Evaporation From Class "A" Pans
In Irrigated Pastures and Turfgrass to Estimate Weekly Crop Evapotranspiration
for Several Crops in California's Central Valley (Redding to Bakersfield)
(Page 3 of 4)

Weekly Period Ending	Milo [5/]			Cotton [5/]			Tomatoes (Processing) [5/]		
	5/15-10/2	6/15-10/19	7/15-11/18	4/1-9/30	4/15-10/4	4/29-10/28	3/1-8/16	4/1-9/9	6/1-9/18
1/07									
1/14									
1/21									
1/28									
2/04									
2/11									
2/18									
2/25									
3/04							0.20		
3/11							0.20		
3/18							0.20		
3/25							0.20		
4/1							0.20		
4/8				0.10			0.21	0.20	
4/15				0.10	0.97		0.22	0.20	
4/22				0.11	0.09		0.24	0.20	
4/29				0.12	0.10		0.27	0.21	
5/06				0.14	0.13	0.14	0.34	0.22	
5/13				0.17	0.16	0.15	0.41	0.24	
5/20	0.11			0.22	0.20	0.16	0.54	0.29	
5/27	0.13			0.28	0.24	0.20	0.67	0.36	
6/03	0.14			0.36	0.33	0.30	0.79	0.43	0.17
6/10	0.16			0.47	0.46	0.44	0.88	0.55	0.22
6/17	0.18	0.10		0.58	0.59	0.57	0.92	0.69	0.30
6/24	0.25	0.11		0.70	0.71	0.70	0.93	0.82	0.37
7/01	0.32	0.14		0.83	0.82	0.81	0.93	0.89	0.47
7/08	0.60	0.17		0.94	0.94	0.90	0.91	0.92	0.61
7/15	0.85	0.25		1.00	0.98	0.95	0.87	0.93	0.76
7/22	0.90	0.43	0.10	1.00	1.00	0.99	0.82	0.93	0.87
7/29	0.90	0.79	0.11	1.00	1.00	1.00	0.76	0.90	0.90
8/05	0.90	0.90	0.14	1.00	1.00	1.00	0.71	0.86	0.93
8/12	0.88	0.91	0.17	0.99	1.00	1.00	0.65	0.82	0.93
8/19	0.86	0.91	0.25	0.97	0.99	1.00		0.75	0.92
8/26	0.84	0.90	0.43	0.91	0.97	1.00		0.69	0.89
9/02	0.80	0.88	0.79	0.82	0.92	0.98		0.63	0.85
9/09	0.76	0.86	0.90	0.73	0.85	0.92		0.57	0.80
9/16	0.71	0.81	0.91	0.62	0.76	0.85			0.74
9/23	0.65	0.73	0.91	0.51	0.65	0.77			0.68
9/30	0.57	0.64	0.90	0.44	0.55	0.67			
10/07		0.53	0.88		0.45	0.57			
10/14		0.40	0.86		0.36	0.48			
10/21			0.81			0.38			
10/28			0.73			0.29			
11/4			0.64						
11/11			0.53						
11/18			0.40						
11/25									
12/02									
12/09									
12/16									
12/23									
12/30									

NOTE: All footnotes are on page 2 (of 4).

Table J-1. Kp Ratios[1] (Coefficients) for Adjusting Evaporation from Class "A" Pans in Irrigated Pastures and Turfgrass to Estimate Weekly Crop Evapotranspiration for Several Crops in California's Central Valley (Redding to Bakersfield)

(Page 4 of 4)

Weekly Period Ending	Small Grains[5]						Citrus
	10/15–6/3	10/28–5/13	11/15–7/4	12/2–6/3	12/15–8/3	1/1–7/1	1/1–12/31
1/07	0.78	0.70	0.43	0.30	0.22	0.18	0.60
1/14	0.84	0.78	0.52	0.36	0.26	0.20	0.60
1/21	0.89	0.84	0.62	0.43	0.30	0.22	0.60
1/28	0.94	0.89	0.70	0.52	0.36	0.26	0.60
2/04	0.96	0.94	0.78	0.62	0.43	0.30	0.60
2/11	0.98	0.96	0.84	0.70	0.52	0.36	0.59
2/18	0.98	0.98	0.89	0.78	0.62	0.43	0.59
2/25	0.98	0.98	0.94	0.84	0.70	0.52	0.58
3/04	0.98	0.97	0.96	0.89	0.78	0.62	0.58
3/11	0.98	0.95	0.98	0.94	0.84	0.70	0.57
3/18	0.97	0.94	0.98	0.96	0.89	0.78	0.56
3/25	0.95	0.92	0.98	0.98	0.94	0.78	0.62
4/01	0.94	0.87	0.98	0.98	0.96	0.89	0.56
4/08	0.92	0.78	0.98	0.97	0.98	0.94	0.56
4/15	0.87	0.67	0.97	0.95	0.98	0.96	0.56
4/22	0.78	0.54	0.95	0.94	0.98	0.98	0.56
4/29	0.67	0.41	0.94	0.92	0.98	0.98	0.56
5/06	0.54	0.28	0.92	0.87	0.98	0.97	0.56
5/13	0.41	0.20	0.87	0.78	0.97	0.95	0.56
5/20	0.28		0.78	0.67	0.95	0.94	0.56
5/27	0.20		0.67	0.54	0.94	0.92	0.55
6/03	0.14		0.54	0.41	0.92	0.87	0.54
6/10			0.41		0.87	0.78	0.53
6/17			0.28		0.78	0.67	0.52
6/24			0.20		0.67	0.54	0.52
7/01			0.14		0.54	0.41	0.52
7/08					0.41		0.52
7/15					0.28		0.52
7/22					0.20		0.52
7/29					0.14		0.52
8/05							0.52
8/12							0.52
8/19							0.52
8/26							0.52
9/02							0.52
9/09							0.52
9/16							0.52
9/23							0.52
9/30							0.53
10/07							0.55
10/14							0.56
10/21	0.17						0.56
10/28	0.18						0.56
11/04	0.20	0.18					0.56
11/11	0.23	0.20					0.56
11/18	0.26	0.23	0.17				0.56
11/25	0.30	0.26	0.18				0.56
12/02	0.36	0.30	0.20				0.56
12/09	0.43	0.36	0.22	0.18			0.56
12/16	0.52	0.43	0.26	0.20	0.17		0.56
12/23	0.62	0.52	0.30	0.22	0.18		0.56
12/30	0.70	0.62	0.36	0.26	0.20		0.58

NOTE: All footnotes are on page 2 (of 4).

Table J-2

Adjustment Factors for Evaporation Data from Class "A" Pans in Irrigated Pastures and Turfgrass as a Function of Wind and Relative Humidity

Avg Daily Rel Humidity	Total Miles of Wind per day									
	50	100	150	200	250	300	350	400	450	500
100						0.99	0.97	0.94	0.90	0.86
90					0.99	0.97	0.95	0.92	0.88	0.84
80				0.99	0.97	0.94	0.92	0.89	0.86	0.82
70				0.98	0.96	0.93	0.91	0.88	0.85	0.81
60			0.98	0.97	0.95	0.92	0.89	0.87	0.83	0.79
50			0.97	0.95	0.93	0.91	0.88	0.85	0.82	0.78
40		0.98	0.96	0.94	0.91	0.89	0.86	0.83	0.80	0.76
30	0.98	0.96	0.94	0.92	0.90	0.87	0.84	0.81	0.78	0.75
20	0.96	0.94	0.92	0.90	0.88	0.85	0.82	0.79	0.76	0.73
10	—	—	—	—	—	—	—	—	—	—

To adjust pan evaporation, multiply by the appropriate factor. To estimate potential crop evapotranspiration, pan evaporation must be adjusted before the Kp coefficient is applied.

Source: W. O. Pruitt

Table J-3. Kc Ratios[1] (Coefficients) for Adjusting CIMIS-ETo (ETgrass turf) to Estimated Weekly Crop Evapotranspiration for Several Crops in California's Central Valley (Redding to Bakersfield)
(Page 1 of 4)

Weekly Period Ending	Alfalfa (Hay)[2]	Olives	Deciduous Orchard				Sugar Beets[5]		
			Cover[3]	Clean Tilled[4]					
	1/1-12/31	1/1-12/31	1/1-12/31	2/15-11/8	3/1-11/8	4/15-11/8	2/1-8/30	3/1-11/1	4/1-12/30
1/07	1.07		1.00						
1/14	1.07		1.00						
1/21	1.06		1.00						
1/28	1.04		1.00						
2/04	1.03		1.00				0.27		
2/11	1.03		1.00				0.27		
2/18	1.01		1.00	0.55			0.27		
2/25	1.01		1.00	0.59			0.27		
3/04	1.00		1.00	0.60	0.54		0.28	0.14	
3/11	0.99		1.03	0.64	0.58		0.29	0.17	
3/18	0.99		1.04	0.66	0.60		0.31	0.21	
3/25	0.99		1.05	0.69	0.64		0.35	0-29	
4/01	0.99		1.08	0.73	0.66		0.39	0.35	
4/08	0.99		1.09	0.75	0.67		0.47	0.42	0.14
4/15	0.97		1.10	0.77	0.72		0.55	0.49	0.17
4/22	0.97		1.12	0.81	0.74	0.53	0.69	0.55	0.20
4/29	0.97		1.14	0.83	0.77	0.56	0.87	0.83	0.28
5/06	0.97	0.64	1.15	0.86	0.81	0.59	1.00	0.99	0.35
5/13	0.97	0.64	1.17	0.87	0.83	0.63	1.09	1.08	0.41
5/20	0.97	0.64	1.18	0.88	0.86	0.65	1.13	1.13	0.49
5/27	0.97	0.64	1.19	0.91	0.87	0.68	1.17	1.15	0.55
6/03	0.97	0.64	1.19	0.94	0.88	0.72	1.17	1.17	0.83
6/10	0.97	0.64	1.20	0.95	0.91	0.74	1.17	1.17	0.99
6/17	0.97	0.64	1.20	0.96	0.94	0.77	1.17	1.17	1.08
6/24	0.97	0.64	1.20	0.96	0.95	0.81	1.18	1.17	1.13
7/01	0.97	0.64	1.20	0.96	0.95	0.83	1.18	1.18	1.15
7/08	0.97	0.64	1.20	0.96	0.96	0.86	1.17	1.18	1.17
7/15	0.97	0.64	1.22	0.96	0.96	0.87	1.17	1.18	1.17
7/22	0.97	0.64	1.22	0.96	0.96	0.88	1.17	1.18	1.17
7/29	0.97	0.64	1.20	0.96	0.96	0.91	1.17	1.18	1.17
8/05	0.97	0.64	1.20	0.96	0.96	0.94	1.15	1.18	1.18
8/12	0.97	0.64	1.20	0.96	0.95	0.95	1.13	1.18	1.18
8/19	0.97	0.64	1.19	0.95	0.96	0.96	1.08	1.18	1.18
8/26	0.97	0.64	1.18	0.92	0.96	0.96	1.04	1.18	1.18
9/02	0.97	0.64	1.17	0.90	0.95	0.96		1.18	1.18
9/09	0.97		1.15	0.86	0.92	0.96		1.17	1.18
9/16	0.97		1.14	0.83	0.90	0.96		1.14	1.18
9/23	0.99		1.14	0.80	0.87	0.97		1.13	1.19
9/30	0.99		1.12	0.77	0.84	0.97		1.12	1.19
10/07	0.99		1.09	0.73	0.80	0.97		1.10	1.19
10/14	1.00		1.09	0.68	0.78	0.99		1.10	1.21
10/21	1.01		1.07	0.63	0.75	0.99		1.12	1.23
10/28	1.01		1.07	0.57	0.69	0.96		1.12	1.23
11/04	1.01		1.04	0.53	0.63	0.93			1.23
11/11	1.03		1.03			0.90			1.23
11/18	1.04		1.01						1.22
11/25	1.04		1.00						1.19
12/02	1.06		1.00						1.19
12/09	1.07		1.00						1.20
12/16	1.07		1.00						1.18
12/23	1.09		1.00						1.20
12/30	1.09		1.00						1.20

NOTE: All footnotes are on page 2 (of 4)

Table J-3. Kc Ratios[1/] (Coefficients) for Adjusting CIMIS-ETo (ETgrass turf)
to Estimated Weekly Crop Evapotranspiration for Several Crops
in California's Central Valley (Redding to Bakersfield)
(Page 2 of 4)

Weekly Period Ending	Table Grapes[4/]			Rice[6/]		Corn[5/]			Dry Beans (Pinto)[5/]	
	3/1-11/8	3/15-11/8	4/15-11/8	4/15-9/19	5/15-10/9	4/1-8/26	5/1-9/12	6/15-10/19	5/1-8/21	6/1-9/21
3/04	0.13									
3/11	0.14									
3/18	0.17	0.13								
3/25	0.23	0.14								
4/01	0.42	0.17								
4/08	0.52	0.23				0.19				
4/15	0.59	0.41				0.21				
4/22	0.64	0.51	0.13	1.01		0.22				
4/29	0.69	0.59	0.14	1.02		0.26				
5/06	0.73	0.64	0.17	1.04		0.32	0.18		0.13	
5/13	0.77	0.69	0.23	1.04		0.42	0.19		0.13	
5/20	0.81	0.73	0.41	1.06	1.01	0.55	0.23		0.13	
5/27	0.83	0.77	0.51	1.09	1.02	0.70	0.29		0.24	
6/03	0.85	0.81	0.59	1.14	1.04	0.90	0.38		0.78	0.12
6/10	0.85	0.83	0.64	1.19	1.04	1.10	0.47		1.05	0.14
6/17	0.85	0.85	0.69	1.24	1.06	1.19	0.64	0.18	1.13	0.45
6/24	0.85	0.85	0.73	1.27	1.09	1.22	0.82	0.19	1.15	0.53
7/01	0.85	0.85	0.77	1.28	1.04	1.22	1.00	0.26	1.15	0.78
7/08	0.85	0.85	0.81	1.28	1.19	1.22	1.13	0.38	1.15	1.05
7/15	0.85	0.85	0.83	1.28	1.24	1.20	1.22	0.60	1.15	1.13
7/22	0.85	0.85	0.85	1.28	1.27	1.18	1.22	0.86	1.12	1.15
7/29	0.82	0.85	0.85	1.28	1.28	1.12	1.19	1.06	1.00	1.15
8/05	0.78	0.85	0.85	1.28	1.28	1.01	1.15	1.15	0.79	1.15
8/12	0.74	0.82	0.85	1.27	1.28	0.91	1.08	1.20	0.56	1.15
8/19	0.68	0.78	0.85	1.26	1.28	0.78	0.97	1.22	0.32	1.12
8/26	0.63	0.74	0.85	1.19	1.28	0.62	0.85	1.22		1.00
9/02	0.54	0.68	0.85	1.13	1.28		0.73	1.20		0.79
9/09	0.46	0.63	0.82	1.06	1.27		0.56	1.18		0.56
9/16	0.38	0.54	0.82		1.26			1.13		0.32
9/23	0.26	0.47	0.79		1.19			1.03		
9/30	0.26	0.39	0.75		1.13			0.91		
10/07	0.26	0.26	0.69		1.06			0.79		
10/14	0.26	0.26	0.64					0.67		
10/21	0.27	0.27	0.56							
10/28	0.27	0.27	0.48							
11/04	0.27	0.27	0.40							
11/11			0.27							

[1/] These Kc ratios are approximate and tentative. They were obtained as follows: Kp(crop) ÷ Kp(mixed pasture) ≈ Kc. Evaporation losses from a moist soil surface are very high for several days following each irrigation during plant emergence and establishment. These ratios do not account for this accelerated loss but do assume that soil moisture is not limiting plant growth.

[2/] Alfalfa hay ratios are derived from total monthly ET. These ratios do not reflect the true weekly fluctuations in ET rates that occur continuously from mowing to full effective cover.

[3/] Green all year due to cover crop.

[4/] Average bloom and leaf-drop dates.

[5/] Plant emergence and crop harvest or senescence dates.

[6/] Continuously saturated soil. Ratio suitability for wild rice is not known.

Table J-3. Kc Ratios[1/] (Coefficients) for Adjusting CIMIS-ETo (ETgrass turf)
to Estimated Weekly Crop Evapotranspiration for Several Crops
in California's Central Valley (Redding to Bakersfield)
(Page 3 of 4)

Weekly Period Ending	Milo[5/]			Cotton[5/]			Tomatoes, Processing[5/]		
	5/15-10/2	6/15-10/19	7/15-11/18	4/1-9/30	4/15-10/4	4/29-10/28	3/1-8/16	4/1-9/9	6/1-9/18
1/07									
1/14									
1/21									
1/28									
2/04									
2/11									
2/18									
2/25									
3/04							0.26		
3/11							0.26		
3/18							0.26		
3/25							0.26		
4/01							0.26		
4/08				0.13			0.27	0.26	
4/15				0.13			0.28	0.26	
4/22				0.14	0.12		0.31	0.26	
4/29				0.15	0.13		0.35	0.27	
5/06				0.18	0.17	0.18	0.44	0.28	
5/13				0.22	0.20	0.19	0.53	0.31	
5/20	0.14			0.28	0.26	0.20	0.69	0.37	
5/27	0.17			0.36	0.31	0.26	0.86	0.46	
6/03	0.18			0.46	0.42	0.38	1.01	0.55	0.22
6/10	0.20			0.60	0.59	0.56	1.13	0.70	0.28
6/17	0.23	0.13		0.74	0.76	0.73	1.18	0.88	0.38
6/24	0.32	0.14		0.90	0.91	0.90	1.19	1.05	0.47
7/01	0.41	0.18		1.06	1.05	1.04	1.19	1.14	0.60
7/08	0.77	0.22		1.20	1.20	1.15	1.17	1.18	0.78
7/15	1.09	0.32		1.28	1.26	1.22	1.12	1.19	0.97
7/22	1.15	0.55	0.13	1.28	1.28	1.27	1.05	1.19	1.12
7/29	1.15	1.01	0.14	1.28	1.28	1.28	0.97	1.15	1.15
8/05	1.15	1.15	0.18	1.28	1.28	1.28	0.91	1.10	1.19
8/12	1.13	1.17	0.22	1.27	1.28	1.28	0.83	1.05	1.19
8/19	1.10	1.17	0.32	1.24	1.27	1.28		0.96	1.18
8/26	1.08	1.15	0.55	1.17	1.24	1.28		0.88	1.14
9/02	1.02	1.13	1.01	1.05	1.18	1.26		0.81	1.09
9/09	0.97	1.10	1.15	0.94	1.09	1.18		0.73	1.02
9/16	0.91	1.04	1.17	0.79	0.97	1.09			0.95
9/23	0.84	0.95	1.18	0.66	0.84	1.00			0.87
9/30	0.74	0.83	1.17	0.57	0.71	0.87			
10/07		0.69	1.14		0.58	0.74			
10/14		0.53	1.13		0.47	0.63			
10/21			1.08			0.51			
10/28			0.97			0.39			
11/04			0.85						
11/11			0.71						
11/18			0.55						
11/25									

NOTE: All footnotes are on page 2 (of 4).

Table J-3. Kc Ratios[1] (Coefficients) for Adjusting CIMIS-ETo (ETgrass turf) to Estimated Weekly Crop Evapotranspiration for Several Crops in California's Central Valley (Redding to Bakersfield)
(Page 4 of 4)

Weekly Period Ending	Small Grains[5]						Citrus
	10/15-6/3	10/28-5/13	11/15-7/4	12/2-6/3	12/15-8/3	1/1-7/1	1/1-12/31
1/07	1.10	0.99	0.60	0.42	0.31	0.25	0.84
1/14	1.18	1.10	0.73	0.50	0.37	0.28	0.84
1/21	1.24	1.17	0.86	0.60	0.42	0.30	0.83
1/28	1.29	1.22	0.96	0.71	0.49	0.36	0.82
2/04	1.30	1.27	1.05	0.84	0.58	0.40	0.81
2/11	1.32	1.30	1.14	0.95	0.70	0.49	0.80
2/18	1.31	1.31	1.19	1.04	0.83	0.57	0.79
2/25	1.31	1.31	1.25	1.12	0.93	0.69	0.77
3/04	1.29	1.28	1.26	1.17	1.03	0.82	0.76
3/11	1.29	1.25	1.29	1.24	1.10	0.92	0.75
3/18	1.26	1.22	1.27	1.25	1.16	1.01	0.73
3/25	1.23	1.19	1.27	1.27	1.22	1.09	0.73
4/01	1.22	1.13	1.27	1.27	1.25	1.16	0.73
4/08	1.19	1.01	1.27	1.26	1.27	1.22	0.73
4/15	1.12	0.86	1.24	1.22	1.26	1.23	0.72
4/22	1.00	0.69	1.22	1.20	1.26	1.26	0.72
4/29	0.86	0.52	1.20	1.18	1.26	1.26	0.72
5/06	0.69	0.36	1.18	1.11	1.26	1.24	0.72
5/13	0.52	0.26	1.12	1.00	1.24	1.22	0.72
5/20	0.36		1.00	0.86	1.22	1.20	0.72
5/27	0.26		0.86	0.69	1.20	1.18	0.70
6/03	0.18		0.69	0.52	1.18	1.12	0.69
6/10			0.52		1.12	1.00	0.68
6/17			0.36		1.00	0.86	0.67
6/24			0.26		0.86	0.69	0.67
7/01			0.18		0.69	0.52	0.67
7/08					0.52		0.67
7/15					0.36		0.67
7/22					0.26		0.67
7/29					0.18		0.67
8/05							0.67
8/12							0.67
8/19							0.67
8/26							0.67
9/02							0.67
9/09							0.67
9/16							0.67
9/23							0.68
9/30							0.69
10/07							0.71
10/14							0.74
10/21	0.23						0.75
10/28	0.24						0.75
11/04	0.27	0.24					0.75
11/11	0.30	0.27					0.76
11/18	0.36	0.32	0.23				0.77
11/25	0.41	0.36	0.25				0.77
12/02	0.50	0.42	0.28				0.78
12/09	0.60	0.51	0.31	0.25			0.79
12/16	0.73	0.60	0.37	0.28	0.24		0.79
12/23	0.89	0.74	0.43	0.31	0.26		0.80
12/30	1.00	0.89	0.51	0.37	0.28		0.83

NOTE: All footnotes are on page 2 (of 4).

Table J-4
Measured Monthly Evapotranspiration for Several Principal Irrigated California Crops (in inches)[a]
(Page 1 of 2)

CROP	LOCATION	METHOD OF MEASUREMENT	OBSERVER	YEAR(S)	ET MEASUREMENT PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	
																		GROWING SEASON	ANNUAL
Alfalfa	Brawley 2 SW	Weighing ET Tank	ARS[b]	1968	Perennial	-	3.2	4.6	7.1	9.4	-	-	-	-	-[c]	-	-	-[d]	-
Alfalfa	Brawley 2 SW	Weighing ET Tank	ARS[b]	1975	Perennial[e]	2.7	2.5	5.0	7.0	10.5	12.3	11.0	10.1	7.4	5.1	3.7	1.9	74.6[d]	79.2
Alfalfa	Brawley 2 SW	Weighing ET Tank	ARS[b]	1976	Perennial	1.9	3.3	4.9	5.8	8.2	9.0	8.3	11.1	7.0	4.5	3.5	1.5	65.6[d]	69.0
Alfalfa	Brawley 2 SW	Weighing ET Tank	ARS[b]	1977	Perennial	2.4	4.2	6.3	8.0	11.5	-	-	-	-	-	-	-	-[d]	-
				AVERAGE		2.3	3.3	5.2	7.0	9.9	10.6	9.6	10.6	7.2	4.8	3.6	1.7	71.8[d]	75.8
Almonds	Wasco 8 SW (ET Plot 45)	Neutron Probe	DWR	1975	Perennial	-	-	1.9	2.6	5.3	6.6	6.2	3.2	1.9	2.3	1.0	0.2	30.0[f]	-
Almonds		Neutron Probe	DWR	1976	Perennial	0.2	0.8	1.8	2.2	4.8	7.3	6.4	3.8	2.1	1.9	0.1	0.3	30.3[f]	31.7
Almonds		Neutron Probe	DWR	1977	Perennial	0.4	0.8	1.4	4.6	4.9	6.6	7.1	4.4	2.1	1.6	1.4	1.0	32.7[f]	36.3
				AVERAGE		0.3	0.8	1.7	3.1	5.0	6.9	6.6	3.8	2.0	1.9	0.8	0.5	31.0[f]	33.4
Barley	Brawley 2 SW	Weighing ET Tank	ARS[b]	1969	12/23/68-5/14/69	2.2	3.6	7.3	7.0	0.9	-	-	-	-	-	-	0.5	21.5	-
Barley	Brawley 2 SW	Weighing ET Tank	ARS[b]	1978	12/12/77-5/15/78	2.0	2.8	5.0	4.2	0.9	-	-	-	-	-	-	0.9	15.8	-
				AVERAGE		2.1	3.2	6.2	5.6	0.9							0.7	18.7	-
Barley	Tulelake	Hydraulic ET Tank	UC[g]	1967	5/16-8/27	-	-	-	-	2.0[h]	7.1	8.2	3.8[i]	-[j]	- -	-	-	21.1[k]	-
Barley	Tulelake	Hydraulic ET Tank	UC[g]	1969	5/2-8/9	-	-	-	-[l]	3.8	6.3	9.6	2.0	-[m]	-	-	-	21.7[k]	-
				AVERAGE		-	-	-	-	2.9	6.7	8.9	2.9	-	-	-	-	21.7[k]	-
Beans (dry)	Davis 2 W	Floating ET Tank	UC[n]	1973	6/15-10/11	-	-	-	-	-	0.9	7.2	8.7	4.4	0.4	-	-	21.6	-
Beans (dry)	Davis 2 W	Floating ET Tank	UC[n]	1976	6/2-9/10	-	-	-	-	-	2.4	8.0	6.1	0.4	-	-	-	16.9	
Beans (dry)	Davis 2 W	Floating ET Tank	UC[n]	1977	6/23-9/27	-	-	-	-	-	1.0	4.6	8.1	4.9	-	-	-	18.6	
				AVERAGE							1.4	6.6	7.6	3.2	0.4			19.2	-
Corn (Field)	Davis 2 W	Floating ET Tank	UC[n]	1974	5/17-9/24	-	-	-	-	0.6	6.1	9.5	8.0	2.9	-	-	-	27.1	-
Corn (Field)	Davis 2 W	Floating ET Tank	UC[n]	1975	5/15-9/20	-	-	-	-	0.7	5.9	8.5	7.4	2.7	-	-	-	25.2	-
				AVERAGE						0.7	6.0	9.0	7.7	2.8				26.2	-
Grass[o]	Davis 2 W	Weighing ET Tank	UC[n]	1972	Perennial	0.9	1.7	3.8	4.8	6.2	7.4	8.0	7.4	4.8	3.0	1.0	1.0	45.4[p]	50.0
Grass[o]	Davis 2 W	Weighing ET Tank	UC[n]	1973	Perennial	1.4	1.3	2.9	5.8	6.9	7.4	7.6	7.0	5.3	3.2	1.5	0.6	46.1[p]	50.9
Grass[o]	Davis 2 W	Weighing ET Tank	UC[n]	1974	Perennial	1.3	1.9	2.7	4.8	6.9	8.5	7.9	7.1	5.3	3.9	1.6	1.3	47.1[p]	53.2
Grass[o]	Davis 2 W	Weighing ET Tank	UC[n]	1975	Perennial	1.2	1.8	3.0	3.9	7.1	8.0	7.6	6.6	4.9	3.1	1.8	1.0	44.2[p]	50.0
Grass[o]	Davis 2 W	Weighing ET Tank	UC[n]	1976	Perennial	1.2	1.7	3.5	4.6	7.3	9.0	7.8	6.3	-	-	-	-	-[p]	-
				AVERAGE		1.2	1.7	3.2	4.8	6.9	8.1	7.8	6.9	5.1	3.3	1.5	1.0	46.1[p]	51.5
Grass[o]	Tulelake	Hydraulic ET Tank	UC[g]	1971	6/18-10/13	-	-	-	-	-	2.4	6.0	6.6	4.6	1.7	-	-	-[r]	-
Grass[o]	Tulelake	Hydraulic ET Tank	UC[g]	1972	5/31-10/27	-	-	-	-	-	7.8[q]	7.5[q]	6.6[q]	4.8[q]	2.3[q]	-	-	-[r]	-
Grass[o]	Tulelake	Hydraulic ET Tank	UC[g]	1973	5/21-10/3	-	-	-	-	2.3	6.8	7.6	7.0	5.3	0.6	-	-	-[r]	-
				AVERAGE							7.3	7.0	6.7	4.9				-[r]	-
Guayule	Brawley 2 SW	Weighing ET Tank	ARS[b]	1981	Perennial	-	-	-	-	-	-	-	-	-	-[s]	2.3	1.2	-[t]	-
Guayule	Brawley 2 SW	Weighing ET Tank	ARS[b]	1982	Perennial	1.3	0.8	2.1	4.0	8.1	7.4	8.3	8.8	6.8	4.2	2.5	1.7	53.0[t]	56.0
Guayule	Brawley 2 SW	Weighing ET Tank	ARS[b]	1983	Perennial	1.2	1.1	2.8	5.1	5.1	6.7	8.0	8.1	6.4	4.5	2.5	1.7	50.3[t]	53.2
Guayule	Brawley 2 SW	Weighing ET Tank	ARS[b]	1984	Perennial	1.5	1.3[u]	0.8	2.7	4.7	7.2	6.7	5.9	4.1	3.3	1.4	0.8	38.1[t]	40.4
				AVERAGE		1.3	1.1	2.4[v]	4.6[v]	6.0	7.1	7.7	7.6	5.8	4.0	2.2	1.4	48.5[t]	51.2

Table J-4

Measured Monthly Evapotranspiration for Several Principal Irrigated California Crops (in inches)[a]

(Page 2 of 2)

CROP	LOCATION	METHOD OF MEASUREMENT	OBSERVER	YEARS(S)	ET MEASUREMENT PERIOD	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS	
																		GROWING SEASON	ANNUAL
Lettuce	Brawley 2 SW	Weighing ET Tank	ARS[b]	1978-79	10/16/78-2/12/79	1.9	0.9	-	-	-	-	-	-	-	1.9	2.0	1.5	8.2	-
Potatoes	Tulelake	Hydraulic ET Tank	UC[g]	1966	7/1-10/2	-	-	-	-	-	-[w]	5.4	8.1	5.7	0.1[x]	-	-	19.3[y]	-
Potatoes	Tulelake	Hydraulic ET Tank	UC[g]	1970	5/20-9/22	-	-	-	-	0.8[z]	3.0	6.2	8.6	1.9[x]	-	-	-	20.5[y]	-
				AVERAGE						0.8	3.0	5.8	8.4	3.8	0.1			21.9[y]	-
Sorghum	Brawley 2 SW	Weighing ET Tank	ARS[b]	1969	7/14-10/13	-	-	-	-	-	-	4.5	9.6	5.3	1.3	-	-	20.7	-
Sorghum	Davis 2 W	Floating ET Tank	UC[n]	1972	5/19-9/18	-	-	-	-	0.6	3.9	8.7	7.0	3.1	-	-	-	23.3	-
Sugar Beets	Brawley 2 SW	Weighing ET Tank	ARS[b]	1974	10/1/73-6/26/74	2.9	3.9	5.2	8.0	9.8	8.8	-	-	-	1.9	2.4	2.6	45.5	-
Sugar Beets	Davis 2 W	Pillow ET Tank	UC[n]	1980	5/6-10/15	-	-	-	-	2.6	3.3	8.4	8.3	6.2	2.5	-	-	31.3	-
Tomatoes	Davis 2 W	Weighing ET Tank	UC[n]	1977	4/28-9/6	-	-	-	-	0.2	4.0	9.1	7.3	0.9	-	-	-	21.5	-
Wheat	Brawley 2 SW	Weighing ET Tank	ARS[b]	1973	12/21/72-5/25/73	1.4	3.2	5.9	8.5	5.5	-	-	-	-	-	-	0.7	24.5	-
Wheat	Davis 2 W	Floating ET Tank	UC[n]	1977	11/10/76-6/10/77	0.8	2.3	5.1	8.1	3.9	1.5	-	-	-	-	0.6	1.2	23.5	-

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a/ Monthly evapotranspiration rates were determined by the Department of Water Resources and cooperating agencies. In most cases, ET rates were obtained under test plot conditions having an atypical upwind field fetch of crop under study. ET measurements from lysimeters with less than a 20-foot diameter include rim effects. Therefore, measured ET may exceed the loss from a large commercial-size field. Some ET measurements are not presented because special requirements of the study caused cultural practices to be atypical of commercial agriculture. Also, some preliminary ET measurements are not presented. These preliminary data and subsequent measurements will be reviewed and considered for presentation in a future edition of Bulletin 113.

b/ Data contributed by C. Arterberry, Laboratory Support Technician, U. S. Department of Agriculture, Agricultural Research Service, Irrigated Desert Research Station, Brawley. ET tank dimensions: 10 ft by 10 ft by 5 ft.

c/ Planted October 1967.

d/ Active growth period, February - November.

e/ Planted October 1974.

f/ Principal growing season, March - October.

g/ Data contributed by W. O. Pruitt. Project leaders were W. O. Pruitt and P. Puri. E. Kucera supervised cultural operations and collection and tabulation of data at the University of California Tulelake Field Station. ET tank dimensions: 5 ft by 6 ft by 4 ft; plot: 106 ft (north-south) by 260 ft (east-west). Typically, a variety of crops were grown in adjoining upwind plots. Predominant daily summer wind (0600 to 1800 hours) averaged 3 mph and blew mainly from the northwest, southwest, west, and southeast (in decreasing frequency).

h/ Planted May 8.

i/ Matured August 28.

j/ Harvested September 26.

k/ ET total for measurement period; ET not measured during entire growing season.

l/ Planted April 27.

m/ Harvested September 12.

n/ Data contributed by W. O. Pruitt, Irrigation Engineer, University of California, Davis. Lysimeter cultural operations, and collection, tabulation, and analysis of the data were performed by S. Von Oettingen, Staff Resources Associate. ET tank dimensions: Floating tank, 20 ft dia. by 3.2 ft deep; Weighing tank, 20 ft dia. by 3 ft deep; Pillow tank, 6 ft by 8 ft by 4 feet deep.

o/ Alta fescue maintained lawn-like in height and appearence, completely shading the ground, and not short of water.

p/ Active growth period, March - October.

q/ Data partially estimated due to end-of-month interpolations made, using the following periods of measurement: 5/31 - 6/14; 6/28 - 7/7; 7/26 - 8/1; 8/4 - 9/8; 9/23 - 10/16.

r/ Active growth period, April - September.

s/ Guayule transplanted into ET tank October 22, 1981.

t/ Active growth period, February - November.

u/ Guayule plants clipped to 1 inch on February 15, 1984.

v/ 1984 ET data not used to compute average.

w/ Planted June 10.

x/ Harvest date unknown

y/ ET total for measurement period. ET not measured during entire growing season.

z/ Planting date unknown.

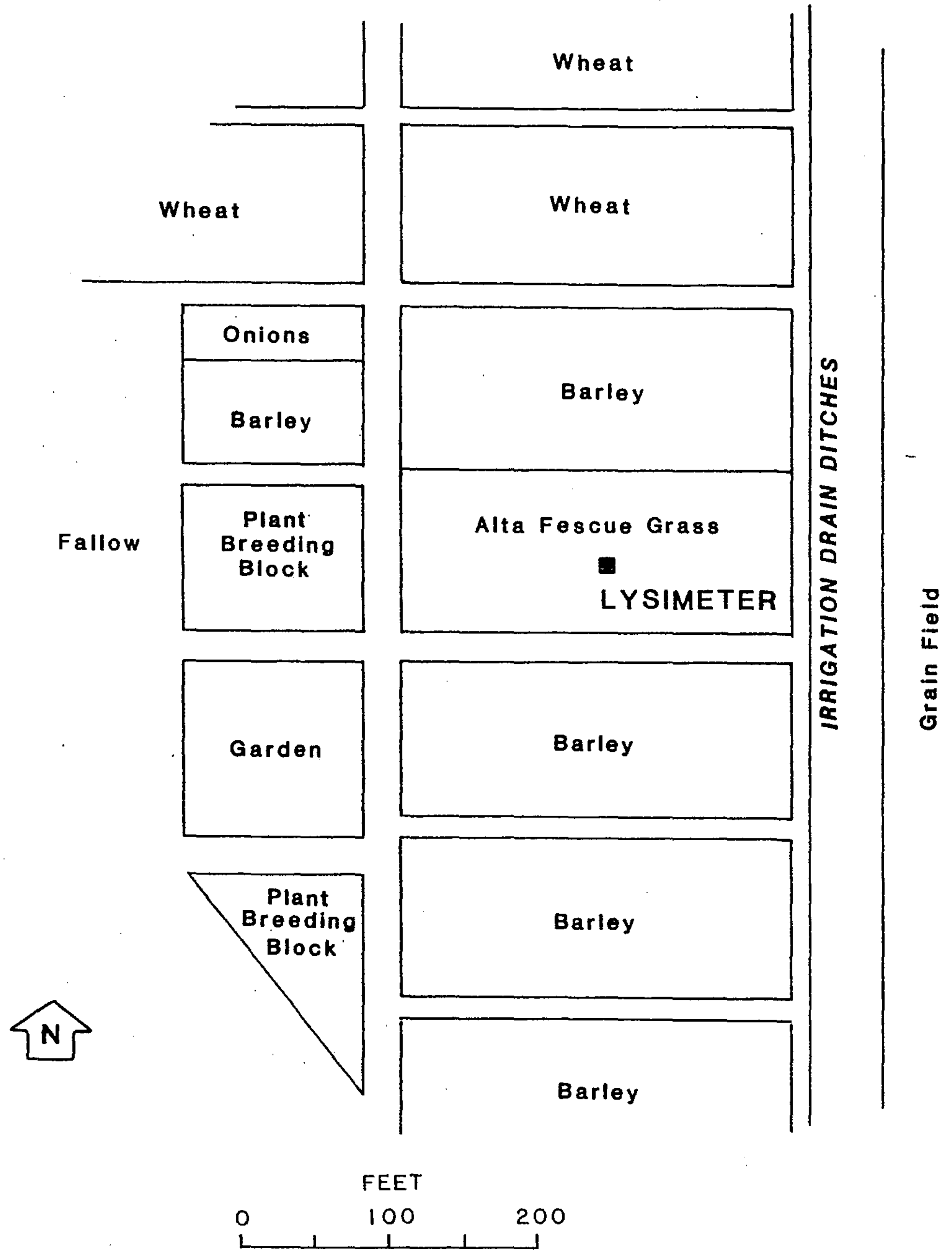

FIGURE J-1. LYSIMETER ENVIRONMENT AT THE UNIVERSITY OF CALIFORNIA TULELAKE FIELD STATION, MAY 1973

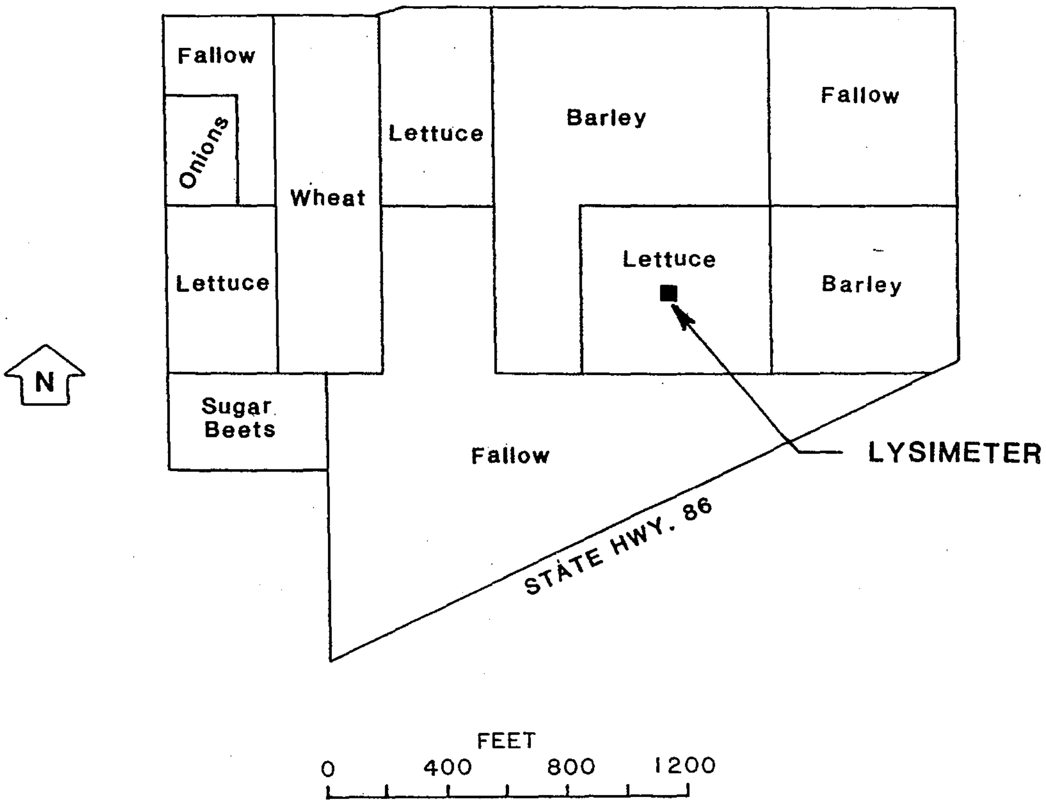

FIGURE J-2. LYSIMETER ENVIRONMENT AT THE IRRIGATED DESERT RESEARCH STATION U. S. AGRICULTURAL RESEARCH SERVICE, BRAWLEY, CALIFORNIA, DECEMBER 1978

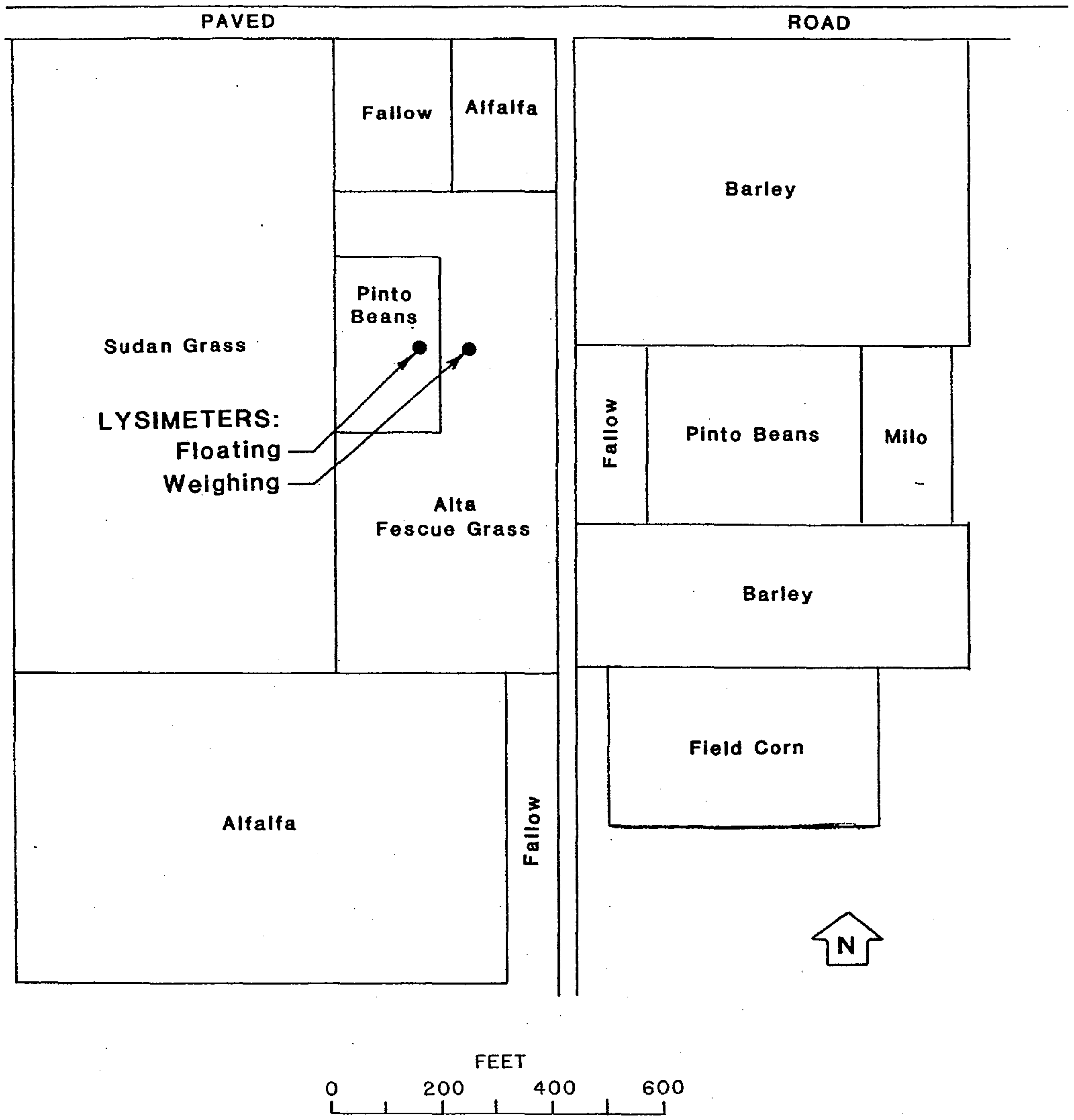

FIGURE J-3. LYSIMETER ENVIRONMENT AT THE UNIVERSITY OF CALIFORNIA, DAVIS JUNE 1973 (Prevailing winds are north and southwest)

CONVERSION FACTORS

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0.03937	25.4
	centimetres (cm) for snow depth	inches (in)	0.3937	2.54
	metres (m)	feet (ft)	3.2808	0.3048
	kilometres (km)	miles (mi)	0.62139	1.6093
Area	square millimetres (mm^2)	square inches (in^2)	0.00155	645.16
	square metres (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometres (km^2)	square miles (mi^2)	0.3861	2.590
Volume	litres (L)	gallons (gal)	0.26417	3.7854
	megalitres	million gallons (10^6 gal)	0.26417	3.7854
	cubic metres (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic metres (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	litres per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	litres per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lb)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8 × °C)+32	(°F−32)/1.8

State of California—Resources Agency
Department of Water Resources
P.O. Box 942836
Sacramento CA 94236-0001