

RECLAMATION

Managing Water in the West

Weather Based Technologies for Residential Irrigation Scheduling

Technical Review Report

Prepared for Municipal Water
District of Orange County



U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Region
Southern California Area Office

May 2004

TABLE OF CONTENTS

Introduction	3
Weather Based Irrigation Principles	3
Product Features and Comparison Criteria	5
Installation	5
Replacement Controller Versus Receiver Add-on	5
Automatic Run Time Calculation and Adjustment	5
Application and Distribution or Efficiency Rates	5
Irrigation Run-Soak Cycles	6
Rain Sensors and Gages	6
Other Sensors	6
Station Circuit Rating and Terminal Wire Sizes	6
Clock Mode Operation	6
Non-volatile Memory	6
Product Descriptions	6
Aqua Conserve	7
Weathermatic	10
WeatherSet	14
AccuWater	16
ET Water Systems	20
HydroPoint	23
Irrisoft	25
Product Features Matrix	29
Summary of Product Features	30

Introduction

Water agencies implementing water use efficiency programs have long struggled to achieve quantifiable and reliable water savings in residential landscapes. Historically, programs targeting residential landscape savings have focused on education including irrigation system maintenance, irrigation scheduling and climate appropriate plantings. Although these efforts have garnered savings, these savings are usually short lived as newly acquired techniques are readily forgotten.

In the late 1990's, the Irvine Ranch Water District, Municipal Water District of Orange County and Metropolitan Water District of Southern California learned about an emerging irrigation management technology now dubbed "Smart Irrigation Controllers" or "Weather-based Irrigation Timers". This technology removes the need for homeowners to make regular scheduling adjustments because the controller or timer adjusts the schedule automatically as weather changes. A water savings evaluation was implemented known as the "Residential Weather-Based Irrigation Scheduling ñ The Irvine ET Controller Study". This evaluation identified single-family home savings rate of 37 gallons per day. Alas, an opportunity for quantifiable and reliable residential landscape water savings had materialized.

As this study was concluding, cities and counties throughout the State were establishing new educational programs to increase public awareness to reduce non-point source pollution. This awareness brought about a second study to evaluate the linkage between improved residential irrigation management and reduced dry-weather runoff. The "Residential Runoff

Reduction Study" found comparable water savings of 42 gallons per day per single-family home and also quantified a reduction in runoff ranging from 64 to 71 percent. With this change in runoff volume, concentrations of pollutants did not change therefore reducing pollution by a like amount.

Water agencies throughout the country recognize weather-based irrigation timers as an emerging tool to achieve landscape water savings and reduce non-point source pollution. When the first study began, the study team was aware of only two automated controller technologies. Today, several different smart or weather-based irrigation controller manufacturers exist and others are quickly emerging into the marketplace.

In 2003, the Municipal Water District of Orange County approached the U.S. Bureau of Reclamation, Southern California Area Office to provide an objective evaluation of all the residential irrigation controller technologies that was available to consumers. The purpose of this evaluation is to document the overall status of residential technologies along with a general description of how each technology operates. From this information, water agencies can quickly gain knowledge about the technology for use in their incentive programs.

Weather Based Irrigation Principles

All of the products reviewed operate based on the principle of scheduling irrigation, based on evapotranspiration (ET), which is a function of weather conditions and plant type. ET is the quantity of moisture which is both transpired by the

plant and evaporated from the soil and plant surfaces.

Each of the irrigation scheduling systems evaluated utilize micro-processing devices which calculate irrigation schedules based on weather conditions, plant type, and site conditions. A significant factor in comparing the various products is the location at which the weather conditions are measured to calculate ET and monitor rainfall. Since it is cost prohibitive to install and maintain a complete weather station at every site, two techniques are being used to collect weather data and calculate ET. Specifically, ET is calculated either using limited on-site measurements, or using multiple sensors to collect data on each of the daily weather parameters necessary to calculate theoretical ET based on accepted equations, such as the Penman-Monteith Equation. The daily weather parameters required to be input into the Penman-Monteith Equation to calculate reference ET are: maximum and minimum temperatures, maximum and minimum relative humidity, solar radiation, mean air pressure and mean wind speed. The latitude and elevation of the site for which ET is being estimated must also be known.

Three of the products reviewed use on-site weather measurements to calculate ET utilizing either on-site temperature or solar radiation sensors. Two of these also use historic ET data in the ET calculation. The historic ET data used for both products are a function of the site location. This technique is based on the relationship between these two weather factors (temperature and solar radiation) and ET. An obvious consideration with this technique is the accuracy of the historic data relative to a specific site.

Four of the products reviewed calculate ET using a full set of data from local weather stations or a network of weather sensors. The weather station data are collected from public or private weather stations. The weather station and sensor network data are processed by a centralized computer server, and transmitted to the irrigation sites. There are ongoing service provider costs associated with the operation of the weather stations, sensor networks, computers, and information transmission systems associated with these products. These costs are either absorbed by water entities or are paid by the users.

In some cases, compelling data were submitted for this review showing accurate ET calculation and or significant water savings associated with a product. However, given the overall lack of data, it is difficult to draw conclusions about the overall performance of one technique over the other. Both techniques provide potentially effective methods for developing weather based irrigation schedules. Bench test type studies are being conducted by the Metropolitan Water District of Southern California and the University of California at Riverside Cooperative Extension in an effort to better understand the overall advantages and disadvantages associated with these techniques. The findings of these studies should be available during 2004. Additionally, the Center for Irrigation Technology at California State University, Fresno will initiate bench test type product evaluations of most of the products included in this technical review during 2004.

Product Features and Comparison Criteria

Significant product components and irrigation features are discussed below. The discussions identify different methods used to achieve similar results by the various products, and associated advantages and disadvantages.

Installation

Although most of the manufacturers recommend professional installation and programming of their products, several indicate installation and programming can be done by the typical homeowner. Most of the individuals associated with demonstration programs and pilot studies which were interviewed during this review expressed concerns about homeowner installation and programming. It appears the percentage of homeowners actually capable of installing and programming most of these products may be relatively small.

Replacement Controller Versus Receiver Add-on

The primary component of most of the products reviewed is an automatic irrigation controller which would replace an existing clock type controller. Alternatively, two of the products include a receiver or scheduler which is connected to the existing controller. In the case of one of these receivers, cost is a significant attraction. Regardless of cost, the quality of an existing controller should be a factor when considering replacement. If the consumer's existing controller is a high quality unit with adequate features, consideration of an add-on receiver may be warranted. However, the level of automation is limited with these units relative to some of the replacement controller systems. Specifically, the receivers

do not automatically calculate run times. The user must manually calculate run times based on experience and guidelines provided by the manufacturer.

Automatic Run Time Calculation and Adjustment

Most of the products reviewed will automatically generate irrigation schedules for various hydrozones as a function of application rate, plant and soil types, slope and sun/shade conditions, and distribution uniformity. The ability of the controller to accurately generate an efficient and satisfactory schedule is a primary consideration relative to maintaining the health of the plants as well as reducing runoff. As stated above, the manual alternative is inexact and may be difficult to calculate. Regardless of automatic or manual run times, all of the products reviewed have a feature which allows adjustment of station run times by a percentage factor or by minutes. This function gives the user the ability to compensate for inaccurate programming inputs, design/sprinkler inefficiencies, and sun/shade areas. Also, this input serves to ease the mind of the property owner that they have control to slightly regulate watering, thus negating the fear of over/under watering and losing expensive landscape.

Application and Distribution or Efficiency Rates

Some of the products reviewed allow the user to enter actual application rates versus preprogrammed rates based on irrigation type (spray, rotor, drip, etc.), and to enter distribution or efficiency factors. These features provide the user more ability to accurately program the controller to actual site conditions.

Irrigation Run-Soak Cycles

When conditions require multiple run-soak cycles, the soak times should not be more than the maximum needed for efficient irrigation and minimal runoff. In the case that soak times are excessive, the overall irrigation run time could be unacceptable.

Rain Sensors and Gages

With one exception, all of the products reviewed offer a rain sensor or gage with the system or as an optional add-on accessory. In the case of the exception (HydroPoint), the receiver will accept commercially available rain sensors. All of the products have a rain delay feature which is triggered by the rain sensor or gage. Some of the products' rain delay only interrupts ongoing irrigation when significant rainfall is detected. Other systems adjust the irrigation schedule based on the amount of rainfall measured by a gage, or the duration of the rainfall detected by the sensor. No documentation was provided for this review on the accuracy of the sensor based schedule adjustment, and it is assumed the use of a gage for this purpose is a significantly more accurate method. Although some of the systems have the ability to initiate a rain delay or adjust the irrigation schedule based on rainfall measured at a local weather station, the advantage of an on-site rain sensor for interrupting irrigation is obvious.

Other Sensors

Some of the products reviewed include standard or optional wind and temperature sensors. These sensors interrupt or delay irrigation when programmed wind and or temperature conditions are adverse to irrigation. Alternatively, some of the systems delay irrigation based on

wind and temperature conditions measured at a local weather station.

Station Circuit Rating and Terminal Wire Sizes

The compatibility of the existing electrical circuits (wiring from the controller to the station valves) should be considered in the selection a new irrigation controller. The station wire terminals on some of the products reviewed will not accept wire sizes larger than 18 gage. In which case, adapters must be used. Also, the circuit current capacity required for an existing system should be checked prior to installing a new unit. Reports from demonstration studies indicate previous installation problems associated with insufficient circuit capacity to operate some irrigation valves with high circuit resistance.

Clock Mode Operation

Some of the products reviewed will not operate in a standard clock mode. So, if a user elected to discontinue receiving the automatic scheduling service, installation of a new controller would be required.

Non-volatile Memory

Most of the controllers and receivers reviewed have non-volatile memory to protect them during power outages. This provides that the device is not totally dependent on batteries, and the micro-processor programming is saved and reinstated when power returns.

Product Descriptions

The following product descriptions address operational characteristics and features, and include discussions of available information from demonstration and

pilot studies, relative to documented water savings and ET calculation accuracy. Each of the manufacturers were provided copies of the product descriptions, for their input, prior to being incorporated into this report.

Aqua Conserve

Aqua Conserve Incorporated, located in Riverside, California, has been in business since 1996 and is a subsidiary of A-G Sod Farms, which has been in business for over 30 years.

The company manufactures 7 residential ET controller models and an ET based irrigation scheduler, which is used in combination with most existing conventional controllers. All of the controllers, and the scheduler, operate based on adjusted historic ET data; with the adjustment made as a function of on-site temperature sensor readings. An optional rainfall sensor is available as an add-on component to all of the controllers and the scheduler.

Aqua Conserve's residential controllers have been on the market for approximately 4 years, and the irrigation scheduler became available late in 2003. Their commercial controllers have been on the market for approximately 6 years. Information regarding the number of controllers sold is not available from Aqua Conserve.

Four indoor residential models are available which accommodate up to 6, 9 or 14 stations (models ET-6, ET-6M, ET-9 and ET-14). The ET-6M differs from the ET-6

in that it does not have a non-volatile memory. The remaining residential models also are designed for outdoor installation, and will accommodate up to 8 and 12 stations (models ET-8b and ET-12b). Each controller includes one station terminal which may run concurrently with all the other stations, and may be used to control a master valve or drip system. Other than this, the Aqua Conserve controllers will not run multiple stations concurrently. The controllers and the scheduler

include a wired temperature sensor, and optional combined temperature and rain sensor devices are available. All products are available directly from Aqua Conserve by mail and internet order, and through a limited number of local distributors. The retail prices for the controllers, the scheduler, and the temperature and rainfall sensors are summarized in the table below. There are no ongoing service costs associated with these controllers.



Aqua Conserve's ET controllers and irrigation scheduler are preprogrammed with 16 individual historic (10-year) ET curves, each representing certain geographic regions within the states of Arizona, California, Oregon, Washington, Nevada, New Mexico, Colorado and Texas. Refinement of water demands within each of the regions is accomplished by programming month of July total run times specified by Aqua Conserve for certain areas within each region. The

Aqua Conserve Component Retail Prices

Component Type	Model No.	Price
6-Station Indoor Controller	ET-6M	\$129
6-Station Indoor Controller	ET-6	\$169
9-Station Indoor Controller	ET-9	\$235
14-Station Indoor Controller	ET-14	\$325
8-Station Outdoor Controller	ET-8b	\$369
12-Station Outdoor Controller	ET-12b	\$459
Irrigation Scheduler	IS-1	\$99
Wired Temperature/Rainfall Sensor	RTS-2	\$69
Wireless Temperature/Rainfall Sensor	RTS-1	\$129

total run times are specific to plant types and for either spray or rotor type sprinkler heads. As an example, the California coastal/desert ET curve region for Orange County includes 3 of these irrigation scheduling (run time) areas. These areas coincide with CIMIS reference ET zones. Refined run times may be programmed based on the prescribed total run times and soil and slope conditions, per Aqua Conserve's guidelines. Four programs are available with all of the controller models except for the ET-6M, which has 3 programs. The multiple programs allow the user to specify different watering days for different stations. Four run times (3 for the ET-6M) are available for each program to refine the prescribed total run times due to soil and slope conditions. The minimum irrigation frequency for low water requirement or native plants is once per week.

The actual irrigation run times for a given day are dependant on the programming described above and an automatic adjustment made by the controller, based on the measured on-site average temperature. The average temperature for the latest 24-hour period (midnight to midnight) is compared to the preprogrammed historic data, and an adjustment to the

next scheduled irrigation is made if the average temperature measurement varies from the historic data. The run times may also be decreased manually in one percent increments up to 20 percent. The units' accumulation feature eliminates cool period run times which are too short for plant benefit by storing programmed run times, until 50 percent of the July run time has been accumulated before irrigating.

The findings of a 2002 study by the East Bay Municipal Water District (Oakland, California) indicate installation and programming of the Aqua Conserve residential controllers is relatively simple and can be performed by most homeowners. Aqua Conserve provides toll free telephone technical support and provides significant technical information on their internet site. Aqua Conserve will arrange for professional installation and service anywhere in the U.S., upon request. The estimated cost for this service, according to Aqua Conserve, is \$50 to \$100. Aqua Conserve's support system appears to be adequate, and the installation and programming instructions appear to be complete and easy to understand. The only apparent major programming instructions related deficiency concerns programming

for drip irrigation. The instruction manual does not provide information regarding programming the controllers for drip systems.

The Aqua Conserve controller and scheduler units do not come equipped with a rain sensor or rain gage. The optional rain sensor (shut-off) signals the controller once every 20 minutes, initiating the rain delay function when significant rainfall is detected and continues the delay until rainfall ends. In rain delay mode, the controller will not re-initiate irrigation demand calculation for 24-hours once significant rainfall has ceased. Depending on the duration of the rain event, the rain delay may cause the controller to interrupt irrigation for several days. Without the rain sensor, the user has the ability to trip the controller's rain delay feature manually.

The indoor controllers are constructed of plastic, and the outdoor controllers are housed in lockable stainless steel boxes. The indoor models' dimensions are 8.25"6"2" and the outdoor models' dimensions are 9"8.75"3.25". The controller panel includes a dial and push button type controls and a 2-line LED display. All of the controller models and the scheduler include a 24VAC power transformer. The station circuit current capacity 1.0 amperes and the terminals will accept wire sizes of 18 gage or smaller. The controller programming is saved in a non-volatile memory (except for ET-6M), and a back-up battery powers the controller clock in the event of a power outage. In the event of a power outage combined with a dead clock battery, the date and time would have to be reset after replacing the battery, but all station programming would remain stored in memory. The ET-6M must be totally

reprogrammed following a power outage. All Aqua Conserve products come with a limited 3 year warranty.

Based on reports from various pilot studies conducted with Aqua Conserve controllers, it appears significant water savings can be achieved for a relatively low initial cost and no ongoing costs. Significant savings have been reported even when the controllers were used without the temperature and rainfall sensors. Reported outdoor water use savings for pilot studies performed by the City of Denver, Colorado, Sonoma, California, and the Valley of the Moon Water District in Northern California were 21%, 23%, and 28%, respectively.

Currently, the Aqua Conserve internet site includes irrigation scheduling guidelines for certain locations in Arizona, California, Oregon, Washington, Nevada, New Mexico, Colorado and Texas. Aqua Conserve plans to expand this database in the near future, and they will assist users with irrigation scheduling information for other areas, upon request. Even with the prescribed irrigation schedules, some trial and error could be involved in programming these controllers. Depending on site conditions, it appears the potential exists for a relatively high level of user monitoring and manual adjustment of run times could be required of the user to improve on the basic scheduling guidance provided by Aqua Conserve. For example, based on the significant variance in the run times specified for given plant types in the 3 different areas within Orange County, the specified run times may not fit for a user located on the border of two of these areas, or in a microclimate area not representative of the overall area. In which case, the user would be required to moni-

for operation and make manual adjustments, as recommended by Aqua Conserve.

Although the 16 run times available with these controllers (4 per program) should be adequate to prevent run off and inadequate irrigation, when properly programmed, the programming process for numerous multiple start times could be difficult for some users. The user must manually calculate the start times using irrigation scheduling guidelines provided on the company's internet site, and enter them into the multiple programs. It appears professional installation could be warranted in such cases.

The Aqua Conserve products offer a proven and competitively priced alternative to limited areas in the western U.S., and the company plans to increase service areas as market growth dictates. Participants in demonstration studies report the Aqua Conserve controllers tend to over-irrigate, but that this can be compensated by using the manual adjustment feature.

Weathermatic

Weathermatic, established in 1945, is a worldwide manufacturing company of a full line of irrigation products. The company, headquartered in Dallas, Texas, began developing water conserving products in the 1950's when it used soil moisture sensors which were later followed by its innovation of the industry's first rain sensor shut off device in the 1970's.

The Weathermatic ET controller technology patent was filed in 1998 and granted in 2000. The unit accepts user inputs by zone for sprinkler type, plant type, soil type, slope, and a zone fine-tune adjustment factor. The unit then incorporates a



ZIP code input (for solar radiation) and an onsite weather station (sensing temperature and rainfall) to perform real time ET measurements that are used with user inputs to calculate proper zone run times, including cycle/soak, at user selected start times and watering days. No historical weather information is used in the unit's calculations and no offsite weather information is gathered so there are no ongoing costs associated with operation. After 8 years of development, testing, and field trials, the ET controller line is scheduled for worldwide release in November of 2004 with capacity in excess of 100,000 units for the first year of production.

The Weathermatic residential controller platform is built around a programming module that is incorporated in a residential housing (4 - 16 zones). Four zone modules allow expandability for varying landscape sizes. All residential units are suitable for either indoor or outdoor installation and are shipped standard with a pre-wired plug-in line cord and mounting bracket for easy installation. The unit is powered with an internal transformer accepting 120 or 240 volts with 24 VAC output (1.5 amps) to zones capable of running 4 zone valves concurrently or 3

zone valves with a master valve. Wire sizes accepted range from 14 to 18 gauge and the unit is 10" tall by 9" wide.

The unit has advanced functions including zone-to-zone and master valve timing delays as well as a unique diagnostic function that displays the electrical current by zone for troubleshooting. Additionally, the user can omit specific calendar event dates, days of the week, and times of the day when no watering is allowed. The remote control option allows the programming module to be used as a remote (range 600 feet line of sight) and also enables the programming module to be mounted independent of the base housing in a user-friendly location (e.g. kitchen or utility room).

The onsite weather station includes a temperature sensor and rain sensor. The unit has a microprocessor to record and process measurements. The temperature-sensing unit, designed for a very precise measurement of ambient air temperature, is encased in a solar shield and white in color to avoid strict mounting location requirements. Both wired and wireless weather station units are offered.

The planned list prices for the controllers range from approximately \$135 for the 4-station model to \$240 for the 16-station model. The weather station will have a list price in the \$250 range. Weathermatic plans to partner with its wholesale distributor and contractor network to offer an installed package price of \$349 for select markets, which will be lessened by any local market subsidies and may include a free system audit for further potential water savings (system upgrade costs additional). The controllers will not be available to the consumer directly from Weathermatic, but

will be distributed through their established wholesale suppliers (specialty irrigation suppliers) and installation professionals. The Weathermatic controller/weather station package operates stand-alone and does not require communication with remote servers to obtain weather data or irrigation schedules and no ongoing service costs are associated with the unit.

Installation and programming of the unit is designed to be simple and intuitive for both the novice homeowner and the advanced professional who is familiar with the unit's industry standard programming dial. Advanced user functions are located in an "Advanced Functions" position on the programming dial so as to not complicate the set up for novice users. While programming the unit is simple, Weathermatic recommends installation by a professional who will give the site the highest rate of success for not only controller programming, but also complete system operations with an emphasis on water conservation. Based on Weathermatic's solid reputation and well-established support network, it is reasonable to assume their ET controller technical support system will be adequate. Installation and programming instructions were not available for this review, however, a programming video and DVD will be available to accommodate the standard user manual.

Programming of the "Auto Adjust" ET portion of the controller requires inputs by zone for sprinkler type, plant type, soil type, and slope. Sprinkler type can be entered on a basic level by the user selecting the type of sprinkler in zone ñ SPRAY, ROTOR, or DRIP. A more advanced user can scroll past these basic inputs with default precipitation

rates and prescribe an exact numerical precipitation rate for the zone from .2"/hr to 3.0"/hr. Plant type works similarly to the sprinkler type input in that the user can simply select the type of plant life in the zone - COOL TURF, WARM TURF, ANNUALS, SHRUBS, NATIVE, or TREES. Again, a more advanced user can scroll past these basic inputs with default percentages and prescribe an exact numerical percentage for the zone from 10 to 300% based on the plant life in the zone and sun/shade consideration. The soil type - CLAY, SAND, LOAM - and slope (numerical degree of slope 1 - 25+ degrees) are used to automatically calculate the cycle/soak function by zone.

In addition to these inputs by zone, the user programs the ZIP CODE of the site or, primarily for locations outside the United States, the latitude of the site. This input and the calendar day of the year is used to determine the solar radiation at the site, which is a variable in ET calculation. These static inputs are combined with the dynamic onsite weather station inputs to perform the overall equation that determines proper zone run times. No historical ET information is necessary for the real time ET calculation.

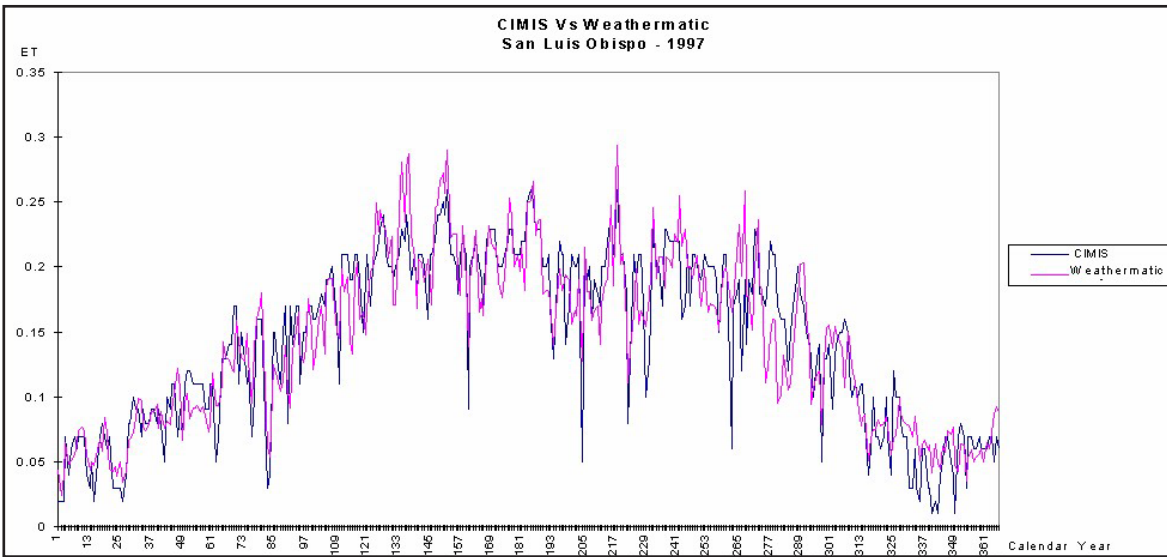
The user will have the ability to fine tune the zone run times by zone through a MORE/LESS function. This allows the user to increase watering by zone up to 25% or decrease watering by up to 50%.

The controller's irrigation schedule is based on the user prescribed irrigation days, start times, and omit times (dates, days, and times of day) so as to conform to local watering restrictions and also accommodate site-specific hydraulic issues, which vary by time of day. Once

programmed, the controller calculates ET for the period beginning at the end of the last irrigation cycle, or measurable rainfall, and ending at the next prescribed irrigation day. Irrigation will occur if the calculated run time is sufficient for an effective irrigation watering. If insufficient demand has not been reached, irrigation will not occur and the controller will carry-over the accumulated ET to the next prescribed irrigation day and time. This accumulation threshold, which prevents ineffective irrigation, is calculated based on a default accumulation factor.

Weathermatic has tested its ET calculation algorithm and controller functionality extensively over the past 8 years. For comparing ET calculations, CIMIS weather station ET calculations were compared to those using the Weathermatic controller/weather station methodology at 10 geographically diverse sites over a 7-year period for 70 years of combined data. The ET results at each site show a very high correlation between the CIMIS weather station ET results and the Weathermatic ET results using the relatively inexpensive onsite weather station. The graph is one example that is representative of the study:

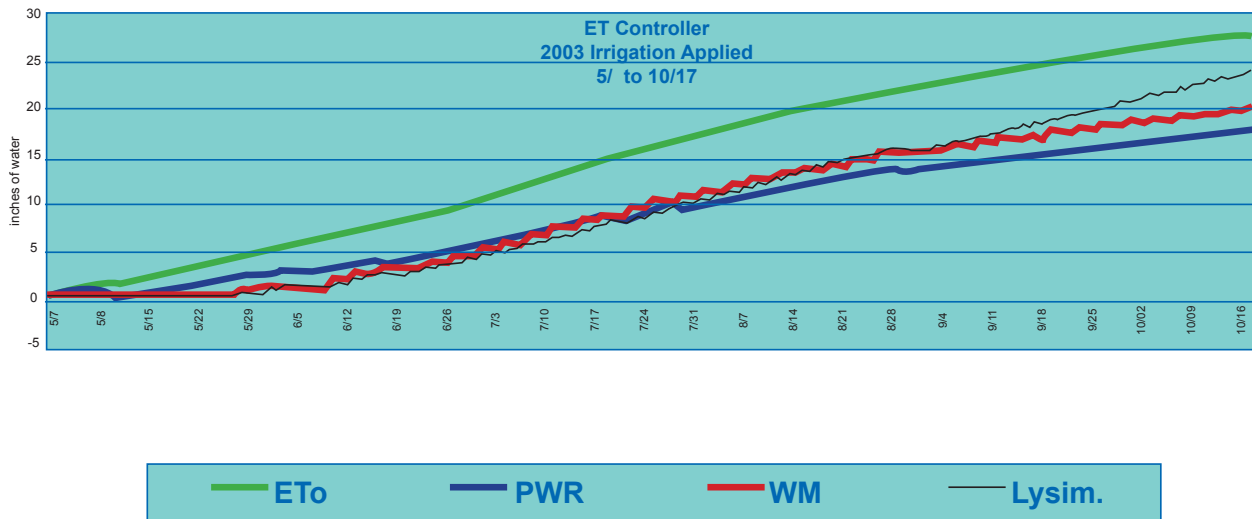
Beyond comparing the ET calculation, the Weathermatic unit has been part of a field study performed by the Northern Colorado Water Conservancy District. This three-year study of the unit analyzes the Weathermatic controller's accumulated water output in comparison to ET (as measured by a lysimeter and onsite weather station) and the plant water requirement of the zone. The results show the Weathermatic unit waters consistently with the varying needs of the plant life as is shown below in the 2003 study:



The Weathermatic unit is also part of a field pilot program conducted by the Marin Municipal Water District. In this study, 13 controllers were installed at 7 sites to compare water usage in 2002 and 2003 to the base year usage in 2001. In 2002, sites installed with the Weathermatic ET controller saved 26%. In 2003, the water savings climbed to 32%. Based on available documentation from this program and the other studies, it appears the Weathermatic controller performs well and yields significant water savings.

Weathermatic's test center is conducting ongoing testing on the controller and weather station in the following areas affecting reliability: mechanical stress testing, environmental testing, software testing, and functional/characterization testing. Additionally, Weathermatic will ensure user friendliness and perform further reliability test during the summer of 2004 at 500 sites in the United States and a number of international countries.

Once the Weathermatic controller becomes available in November, it looks



to be an economical and effective unit with the benefits of real time, onsite ET measurements and inputs by zone for key programming parameters.

WeatherSet

The WeatherSet Company is located in Winnetka,. WeatherSet has manufactured commercial weather based irrigation controllers for landscapes, golf courses and greenhouses since 1979. The company began development of the first residential controller prototypes in 2000, and began marketing the residential controllers in September 2001. Their controllers utilize a WeatherSet designed and custom fabricated solar sensor to approximate on-site ET, and these solar measurements are combined with an on-site rain sensor to automatically adjust irrigation schedules.

include the solar and rain sensors. The WeatherSet controller is a stand-alone controller and does not require communication with remote servers to obtain weather data or irrigation schedules, and there are no ongoing service costs associated with the controller unit. The controller units are available directly from WeatherSet or from their internet site, and the company plans to also distribute the product through select specialty irrigation contractors.

The WeatherSet controller calculates a daily ET estimate based on solar sensor SunFall™ measurements which are logged by the controller on a 2-minute frequency. The sensor must be installed in a mostly sunny location in order to function accurately. From their work with commercial controllers, WeatherSet

The WeatherSet residential controller utilizes the same solar radiation sensor used with the company's greenhouse and commercial irrigation controllers. This solar sensor has reportedly functioned reliably in demanding environmental conditions from Wisconsin to Florida to control greenhouse misting systems both indoors and outdoors since the early 1990's.



Two indoor residential controller models, and five outdoor models are available. Models and low volume prices are summarized in the table below. The prices

reports that "SunFall™" reduces by about two-thirds from a clear day in summer to a clear day in winter, and that their 5 self-adjusting programs follow these changes.

The calculated ET information is com-

WeatherSet Controller Retail Prices

Controller Type	Model No.	Price
8-Station Indoor	WSR8	\$170
12-Station Indoor	WSR12	\$195
8-Station Outdoor	WSC8	\$210
12-Station Outdoor	WSC12	\$235
16-Station Outdoor	WSC16	\$320
20-Station Outdoor	WSC20	\$380
24-Station Outdoor	WSC24	\$440
Irrigation History Function	H-option	\$35

combined with rain sensor data and user programmed information to adjust schedule irrigations. To program the controller for automatic adjustments, the user assigns each station to one of three programs, which are labeled Lawns™ Flowers™, and Shrubs™, and designates irrigation type as either rotor or spray for each station. A runoff factor may also be entered each station to stop runoff. Alternately, the user may program custom run times for each station in one-minute increments from 0 up to 255 minutes.

The controller also includes two low water plant programs (LWU1 and LWU2) for drip systems and native plants. The LWU programs allow the user to manually enter a "Days-Between-Waterings" interval for the hottest time of the year and run times up to 255 minutes. As the solar measurements indicate the ET is falling, the LWU programs automatically increase the "Days-Between-Watering" while holding the run times constant. For example, 10 and 18 day summertime frequencies will automatically increase as solar sensor data measurements a fall in ET. The run times remain constant for valves in the LWU programs. The 2 LWU programs and the Lawns™, Flowers™, and Shrubs™ give WeatherSet controllers 5

self-adjusting programs.

The controller has a manual start function, and an optional irrigation history review function. With the H-option, the controller keeps a running tab of total run time for each station like a water meter records total gallons. The controller's rain sensor is a Hunter Mini-Clik® unit. The sensor signals the controller to interrupt irrigation in its rain shut-off mode, and the rain sensor signals are also used by the controller for irrigation scheduling. The WeatherSet controller is preprogrammed to account for the duration that the rain shut-off circuit has been interrupted when scheduling irrigations.

The WeatherSet irrigation controller provides 7 different runoff factors which are set for each station. A maximum cycle run time of 2, 4, 6, 8, 11, 15, 20 and unlimited minutes per hour is associated with the respective factor. The default cycle limit factor (number 6) is four 4 minutes per hour. As an example, if the controller calculates a total 12 minute run time for a station, this station will be irrigated in three 4-minute increments over a 3-hour period, with the default setting. For stations which generate runoff, WeatherSet recommends the user measure the time required to cause runoff (using the manual run mode), divide the

time by two and use that time to choose the runoff factor for the station. The runoff factor may be shut off to allow continuous watering when required. For example, valves controlling drip systems in LWU programs may best be watered with runoff limit shut off.

The indoor controller cabinets are constructed of aluminum and the indoor power transformer is an external plug-in type unit. The lockable outdoor cabinets are constructed of zinc plated steel with powder coating and stainless steel hinges. The outdoor models include internal power transformers. The station circuit current rating for the indoor units is 0.75 amperes and it is 1.5 amperes for the outdoor units. All models' station circuit terminals will accommodate wiring sizes from 12 to 20 gage. The controller's program memory is non-volatile, and the time-keeping microprocessor chip uses a 3.3V coin-type battery which has a reported life of ten years if no power is applied. When the controller is powered, then the energy of the 10-year battery is not used. WeatherSet provides a standard 3-year warranty with their controllers.

WeatherSet has provided data showing the close correlation between ET estimate calculation by their controller and that calculated by an AZMET (Phoenix, Arizona ET network) weather station. WeatherSet controllers have not been used in any formal demonstration studies and no water savings data was evaluated for this review. It is estimated that approximately 180 commercial units have been installed since 1995, and that most of these controllers remain in use. Approximately 100 residential controllers have been installed since they became available in September 2001.

WeatherSet reports current production

capacity is approximately 25,000 per year, and delivery time is about 8 weeks, depending on volume. WeatherSet has contracted with a major irrigation manufacturer to provide assembly operations, and the above production capacity is based on this recent business arrangement.

WeatherSet reports that most homeowners should be capable of installing the residential controller. WeatherSet believes that programming the residential controllers by the typical homeowner is easy because of Flowers™, Lawn™ and Shrub™ program labeling. Technical support is available by toll free telephone and also through the company's internet site. Service by factory trained contractors is limited to California, Oregon, Washington, and Colorado at this time and will grow as the market expands. The installation and programming instructions, which include directions for locating the solar sensor, appear to be adequate and easy to follow.

The WeatherSet controller appears to be simple stand-alone alternative that should function adequately at most locations. Although WeatherSet reports the technology used in their controllers is proven, water savings data is not available and the track record for their residential unit is limited.

AccuWater

AccuWater, Inc. was incorporated in October 2002 and is based in Austin, Texas. The company is currently in the final stages of developing a centralized weather-based irrigation management system. Their first prototype controller was developed in 2002 and pilot testing has been ongoing since late 2002.

AccuWater plans to begin actively marketing their system within Texas beginning in May 2004. For the rest of 2004, sales outside of Texas will be limited to formal pilot programs sponsored by water authorities.

The AccuWater system schedules irrigation based on ET calculated from local weather data collected through a private network of weather stations and or sensors. Communication and data transfer to the controllers and sensors is accomplished through Internet connection to a centralized computer server operated by AccuWater.

The residential model of the AccuWater controller is an indoor unit with a 16-station capacity, including one station terminal that may run concurrently with all the other stations to control a master valve or drip system. The controller includes a wired tipping bucket type rainfall gage. The planned retail price for the controller will be between \$400 and \$600. The annual service fee will start at \$180 for up to a quarter acre of irrigation landscaping and increase by \$1 per additional thousand square feet of irrigated landscaping, with a cap at \$600 (1.05 acres of irrigated landscaping).

The controller housing is constructed of injection-molded plastic, and the transformer is external to the controller. The

rain gage is commercial grade and is constructed of UV-resistant heavy-gage nylon. The station circuit terminals will accept all common wire sizes and the station circuit current rating is 0.3 amperes. AccuWater plans to provide at least a one-year limited warranty with the controllers and weather stations.



Initially, AccuWater products will only be available directly from the company or AccuWater-certified irrigation contractors. The AccuWater controller requires an "always on" Internet connection (e.g. DSL or cable

modem). In a typical implementation, the controller will piggyback over the homeowner's high-speed Internet connection via a wired or wireless network router. The system does not involve loading any software on the homeowner's computer, nor does the computer need to remain on for the system to operate.

The controller is configured and managed by the end user using a web browser. Because all configuration occurs on the server, configuration and management can be performed from anywhere that the end user can get access to a web browser. Also, since all configuration data is stored on the server, no battery backup is required on the controller.

Information for each controller includes site location (latitude, longitude and ele-



vation), environmental limits (temperature, wind speed), ET lookback period (days), irrigation start time, daily station run limit (number of stations per day), and other operating parameters.

Information programmed for each station includes plant type/coefficient, replacement factor, application rate, irrigated area, maximum run time, minimum delay (soak) time.

Installation of the AccuWater system involves (1) installing the AccuWater controller in place of the existing controller; (2) installing weather instrument(s) and connecting to the new controller; (3) performing an initial site survey to determine flow rates and areas; and (4) configuring the stations and performing a test run of all stations.

Guidelines will be provided with the programming instructions for adjusting the replacement factor to compensate for shade areas and other special needs, and for determining maximum run and delay times for sloped areas.

Adjustments, based on post installation monitoring, are accomplished by changing the replacement factor. AccuWater reports that most users are able to make these adjustments, with technical assistance provided upon request.

The AccuWater controller tightly integrates a weather station and an irrigation controller. It relies on weather monitoring instruments attached to each irrigation controller, and can share weather data between nearby units via the server. The AccuWater controllers send weather data to the server every minute, and the server backfills missing data elements from nearby sites by searching a pre-defined hierarchy. The server then replies to the controller with a complete weather sample for that locale containing temperature, humidity, barometric pressure, wind speed, rainfall and solar radiation. The controller calculates dew point and wind chill for each incoming sample. As a result, the AccuWater controller always knows the current weather conditions and can make decisions (adjust, delay or abandon).

Once a day, the server calculates a schedule for each client based on stored weather data, irrigation history, on-site rainfall history, and the National Weather Service local forecast. The schedule is sent to and stored on the controller until time to execute each record of the schedule. Controller clocks are synchronized with the server to ensure that the entire system remains in synchronization. If a controller is restarted following a power failure, history and schedules will be reloaded from the server on the first connection.

Within an irrigation schedule, one schedule record represents a complete station

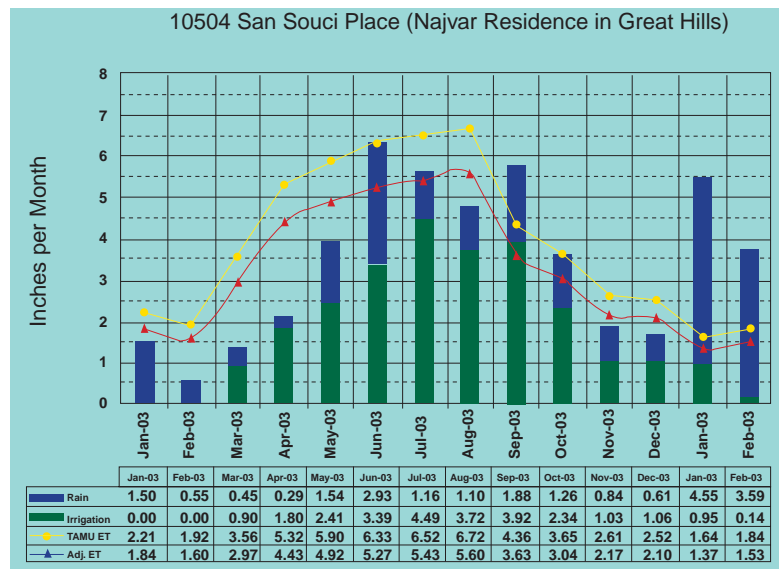
activation for that day. If necessary, the controller will break down a schedule record into multiple intervals to meet the "maximum run time" and "minimum delay" criteria (commonly used in situations where runoff is a problem). The controller will wait until the specified start time for each record, and will then analyze the current (real-time) weather conditions. If conditions are appropriate (no rain or high wind and temperature within limits), the system will open the valve and irrigate the specified zone. When it completes each irrigation segment, the controller will generate an irrigation history record and send it to the centralized server for storage. When the schedule for the next day is generated, the stored irrigation history is used to tabulate previous irrigation amounts.

If the controller determines weather conditions are not appropriate for irrigation, it will wait for conditions to improve. If conditions do not improve before the record expires, no irrigation will occur and a null history record will be generated. If the weather forecast includes a high probability of rain, irrigation may (based on a probabilistic model) be delayed for 24 hours. The unit also has the capability to provide manual irrigation for individual or collections of stations by minutes or inches. Manual irrigation history records are taken into account during normal scheduling, so it is not possible to manipulate the system by occasionally performing manual irrigation.

Since the AccuWater System relies on having a sufficient density of weather stations within their service areas, the com-

pany anticipates the need to locate AccuWater-owned weather stations and weather sensors at selected user sites. All weather stations and sensors will be monitored automatically for suspicious data, and maintenance will be managed by AccuWater. As service areas are developed in other areas of the country, AccuWater may locate additional computer servers within these areas (e.g. West Coast or East Coast) for redundancy and load balancing. At present, all sites are serviced from AccuWater's server facility in Austin, Texas.

By storing all operating data on the server, AccuWater makes it possible to evaluate the effectiveness of controllers (individually or collectively) very easily. The following chart illustrates the effectiveness of one controller and was created in



Microsoft Excel by accessing the AccuWater database.

The above chart is representative of ten similar pilot study data sets, and it should be noted that there was a problem with the ET algorithm that was not recognized and fixed until late May 2003. (The

acronym TAMU is for Texas A&M University.)

AccuWater has implemented the water-rationing algorithm for Austin, Texas, and can add algorithms for any other city (by zip code). This is a user-selectable option. AccuWater plans to make water usage information available to local water authorities (subject to the provisions of its privacy policy) for analysis and to even build in the capability to adjust water usage (if allowed by the end user) during periods of peak usage or water shortage.

AccuWater reports that most homeowners will be capable of installing and configuring the controller. An installation and programming manual was not available at the time of this review. The company plans to make arrangements for local technical service representatives for service calls, and technical support will be available by toll free telephone and through the company's Internet site. Because of its Internet-centric design and web-based controls, the AccuWater system integrates easily into most home automation systems.

AccuWater installed twelve controllers at residential sites in the Austin, Texas area during the winter of 2002/2003, and has monitored these sites as a pilot program. Based on documentation from this program, which has been provided by the company, it appears the system functions well and that it has the potential to yield significant water savings as well as reducing runoff.

Assuming sufficient and accurate weather monitoring data is available within adequate proximity to the user, this system should provide accurate ET-based irrigation scheduling and require minimal moni-

toring and adjustment. The computer interface provides an easy and effective method for monitoring irrigation information and weather conditions. Given the limited track record for this system, long term reliability and operation and maintenance is a concern. The AccuWater System could potentially satisfy the more demanding and affluent portions of the ET irrigation controller market.

ET Water Systems



ET Water Systems (ETWS), based out of Mill Valley, California, is a new manufacturer of weather based irrigation controllers for the residential and commercial markets. The company is currently in the final stages of developing a centralized weather based irrigation management system. ETWS was incorporated in 2002 and their first prototype controller was developed in 2003. The company plans to begin marketing their system in the California, Nevada and Colorado markets beginning in July 2004.

The ETWS system schedules irrigations based on ET data received from existing weather stations and user programmed

information associated with specific landscape features. Currently the ETWS system uses publicly available weather data. The option to install a weather station is also available. A 12-station indoor residential controller is planned for distribution by September 2004, which should retail for approximately \$199. The controller will accommodate an optional rain sensor shut-off or tipping bucket type rain gage, and an outdoor installation enclosure will also be available. An annual service fee will be charged, and it is estimated the fee will be \$48 or less.

ET and precipitation data is automatically retrieved from the Internet each day by the ETWS host server. This data is planned to be obtained from existing weather station networks in the cities where ETWS will market its product. If necessary, ETWS plans to install or use other non-public weather stations to collect ET and precipitation data in locations where sufficient quality data is not available. The server automatically processes the ET data in combination with the user programmed landscape information, to develop irrigation scheduling. The user enters the landscape information from any computer with an Internet connection via the ETWS Internet site. However, a personal computer is not required at the site residence for the system to function.

Communication between the user's controller and the server may be by cellular telephone or land-based telephone link. (It is anticipated most residential users will use land lines.) The ETWS central server communicates with each field controller on a daily basis. During each daily call the ETWS server receives a log of all watering activity since the last call and sends any required scheduling adjustments. The controller will be able to

operate independently if communication to the server is temporarily interrupted. In which case, the controller functions using the latest schedule received from the server, then revises the schedule once reconnected to the server. The ETWS controller can accommodate schedules of any duration and frequency, including schedules that require watering on a very infrequent basis (i.e. every 30 days).

To enter landscape information, a user goes to the ETWS Internet site and logs into their account with a user name and password. The program interface to enter the site specific landscape information is set up with WindowsÆ based pull down menus and appears to be intuitive and easy to use. The program is well organized and covers a comprehensive set of landscape factors including; plant type, irrigation type and optional application rate, soil type, slope, root depth, sun exposure and distribution uniformity. User-defined sprinkler precipitation rate (PR) and sprinkler uniformity (DU) may be entered or default measures may be selected in the absence of precise PR and DU information. A wide selection of plant types are available to select from and multiple plant types may be selected for one station. The program will automatically set the watering schedule based on the plants with the highest water requirement. Irrigation types available include spray, rotor, impact, stream spray, drip emitter, and bubbler. The default distribution uniformity factor is 70 percent. All default settings can be changed at any time by ETWS and each water agency can select the default settings it wishes to use for its customers. The user may also enter non-irrigation days, adjust the total station run times by a percentage factor, and initiate manual irriga-

tions by station. The user will also be able to review system and irrigation history information on ETWS's Internet site from any Internet accessible computer. The ETWS setup program includes help screens to answer questions common to first time users. Once the user becomes familiar with the program, an advanced setup mode may be used which offers a more efficient means of programming. Adjustments to specific site factors may be made at any time via the ETWS Internet site. Site factor changes will generate new irrigation schedules.

The ETWS controller also has an offline programming feature in which users can manually set a watering schedule for each station. This feature is intended to be used during periods when phone service is temporarily unavailable (i.e. newly constructed home prior to sale). Offline programming may be performed at the controller using the keypad and the 2-line LCD display. The manual start mode may also be initiated at the controller. ETWS' objective is for the system to automatically generate, download and execute irrigation schedules. The need for program modification in the field is expected to be very limited.

ETWS reports the irrigation scheduling algorithms used in their system are based on current state-of-the-art horticulture science. The program incorporates all landscape factors needed to accurately determine soil moisture depletion, and irrigation scheduling. ETWS uses a different algorithm for scheduling sprinkler and drip irrigation stations. The company's proprietary algorithms automatically generate daily schedules with station run and soak times based on the station application rate, soil intake rates and slope conditions.. The station run/soak

cycles for each irrigation period remain constant, based on replenishment of a 50 percent plant root zone moisture depletion level. Irrigations are delayed until a soil moisture depletion level of 50 percent is calculated, based on the measured daily ET and rainfall.

ETWS' initial residential controller will use a fabricated metal enclosure. Starting in early 2005, ETWS will manufacture all of its residential controllers with an injection molded plastic enclosure. In addition to the 12 station circuits, the controller is expected to provide a master valve/pump start circuit. Information on the controller's power transformers and station circuit current capacity was not available at the time of this review. The station circuit terminals will accept 12 to 20 gauge size wiring. The controller memory is non-volatile and it includes 9-volt back-up battery for the clock. An optional powder coated lockable steel cabinet for outdoor installation will be available.

Other options will include a rain sensor and a tipping bucket type rain gauge. The rain sensor will cause circuit interruption and simply suspend irrigations when significant rainfall occurs. The rain gauge data would be transmitted to the server for use in irrigation scheduling.

Since telephone communication allows two-way information transfer, ETWS will be able to manage the information received from the individual controllers. This may be beneficial to water agencies by allowing analysis of customer water use data. ETWS plans to provide this information through their Internet site. Also, ETWS may sell their software program to water agencies that would maintain the server and provide the service for their water users. In this case, the water

agency could absorb the ongoing service cost.

The controller will not require professional installation, although the company recommends professional installation and plans to provide factory trained individuals or irrigation contractors to install all units. It is estimated a typical professional commercial installation should take 1 - 3 hours, including a site assessment and discussing the assessment with the user. Typical residential installations will be completed in less time. The professional installation/consultation cost is estimated to be \$75 - \$225 depending on location, size, and other site conditions. Technical support will be available by toll free telephone, in addition to the support provided on the company's Internet site.

The ETWS System has not been included in any demonstration programs and no water savings data were available at the time of this product review. However, ETWS reports about 20 commercial prototype units that were installed during 2003 are functioning well. ETWS plans to provide a 3-year limited warranty with the controller.

The ETWS System appears to be a well designed real-time approach to weather based irrigation scheduling. Depending on the conditions at a given site relative to those measured at the weather station used, the ETWS controllers should function well. Post-installation monitoring and adjustments may be required to address any problems. The controller cost is competitive and ETWS will offer several pricing options for service. Users will have the option of purchasing a one-time service plan for the lifetime of the product (this will be in lieu of annual service fees) in addition to the option of purchasing a

multi-year service plan. The computer interface method of programming and monitoring the system is outstanding. The water use monitoring option should also be attractive to progressive water agencies interested in quantifying water savings.

HydroPoint

WeatherTRAK is the "smart" irrigation controller product of HydroPoint Data



Systems of Petaluma, CA. WeatherTRAK provides a wireless, real-time ET data service combined with a "scheduling engine" that updates irrigation schedules for each valve in a landscape daily. Network Services, which developed the patents on the broadcasting of ET data, began business in 1997. HydroPoint was incorporated in 2002 and now has 1,000 units currently in use.

The WeatherTRAK system uses data from existing ET stations and the National Oceanographic Atmospheric Administration's system of 12,000 nation wide weather stations to deliver ET to any area in the US. The WeatherTRAK

system uses advanced climatologic modeling techniques, developed at Penn State University. This proprietary system is called ET Everywhere, and has proven accuracy to a standard deviation of .01 inch of daily ET down to one square kilometer. The WeatherTRAK ET Everywhere data service provides local ET (microzone) without the need for weather station on site. The HydroPoint Data Center validates the weather data and transmits calculated ET through three satellite servers to each controller everyday. The three satellite services provide over-lapping coverage of the U.S. to ensure signal reception to WeatherTRAK controllers located anywhere.

The WeatherTRAK controller calculates irrigation schedules for each independent valve on a site. The controller does not use pre-set irrigation schedules input by the user. Instead, it asks a series of questions to "understand" the site variables that influence water need. The controller is programmed by entering the following station specific information: sprinkler type or precipitation rate, plant type, soil type, microclimate (sun or shade), slope (including if the valve is at the top, middle or bottom of the slope, and system efficiency (percentage). The schedule for each station is adjusted daily according to the local weather data received via the ET Everywhere Service.

With these inputs, the WeatherTRAK calculates an efficient irrigation schedule for each irrigation valve. Soil moisture depletion tracking, triggered at a 50% depletion level, along with daily ET updates allows the controller to adjust schedules as the weather changes. The number of water days, minutes and cycles (with appropriate soak times between cycles) are generated automatically and change as

weather and water need fluctuates. The WeatherTRAK has an eight week scheduling window. This allows for infrequent watering of low water use or native plants.

The WeatherTRAK has a manual feature providing any amount of time setting to check the irrigation system on a valve by valve basis. An adjust feature provides percentage (in 5% increments) increase or decrease to any independent valve. A rain pause mode allows the user to shut-off irrigation for up to 14 days during or after rain. HydroPoint can also be contacted to automatically "rain pause" controllers and groups of controllers using the wireless data service. Non-water days can be selected. A "help" mode alerts the user to the HydroPoint customer service center toll free telephone number to answer questions and walk users through any situation occurring on the site.

The currently available WeatherTRAK model is an indoor unit which accommodates up to 12 stations. The retail price of the 12 station unit is \$480 and this includes two years of scheduling service. After the initial two years of service an annual fee of \$48 is charged. WeatherTRAK 6 station, 9 station and 12 station models will be available in April 2004. The Toro Company will be selling a full line of residential and commercial models with full WeatherTRAK enabled features available during the summer of 2004. Custom inputs for crop coefficient values, community water restrictions (odd/even or selected watering days) will also be available with the spring 2004 models. The controller is available directly from HydroPoint or through local HydroPoint, Irritrol, and Toro distributors.

The WeatherTRAK residential controller

Summary of WeatherTRAK Demonstration Projects

Test Sponsor	No. of Test Sites
Irvine, California	180
Los Angeles Dept. of Water and Power	540
Boulder, Colorado	10
Colorado State University, Ft. Collins	3
University of Las Vegas, Nevada	15
Santa Barbara, California	200
Lake Arrowhead, California	78
Victor Valley, California	12
Marin, California	8
Park City, Utah	24
Santa Clara Valley Water District, California	125

is a small (7" X 6" X 2") metal and plastic unit for indoor installation. It features a 3 knob interface with 2-line LED display. The power transformer is a 24VAC external plug-in type. Spring models will have hard-wire and 110 volt wiring options. The station circuit current capacity is 1.0 amperes, and the terminals will accept 12 to 20 gage size wiring. Stations run sequentially. WeatherTRAK can accommodate rain shut-off devices, master or pump valves. The WeatherTRAK has a non-volatile memory and does not require a back-up battery.

The WeatherTRAK controller does not require professional installation, although "trained" installation is recommended. Typical installation times, as seen in public agency studies and distribution programs, range from 1 hour to 2.5 hours, depending upon the size of the landscape covered and mounting issues. Installation should include a site assessment and discussing the site irrigation system, how the controller operates with the user. Technical support is available from HydroPoint by a toll free number, on the company internet site and through field "certified" contractors.

The WeatherTRAK controller has been tested (or testing is in progress) in at least 15 public agency settings in the West since 1998. The overall results from these tests indicate sufficient water savings (16% - 58%) and significant reduction in runoff (64% - 71%) have been achieved. Tests locations information is summarized in the table above. The WeatherTRAK controller has a proven track record, and has been on the market longer than any other real-time weather based controller. The WeatherTRAK has added and updated features as public agencies have requested, such as adding the ability to irrigate native and low water use plants in the proper way.

Irrisoft

Irrisoft Incorporated manufactures the Weather Reach Receiver (WR-7). The WR-7 is a weather data receiver which is used in combination with a user's existing irrigation controller to schedule irrigation based on ET demand. Irrisoft has been in business since 1999, and became a subsidiary of Campbell Scientific Company during 2001. The WR-7 has been on the market since July 2002, and



approximately 600 units are currently in use.

The Weather Reach System works in conjunction with local Campbell Scientific weather stations and centralized computer servers using Irrisoft software to calculate local ET based on real-time climatic data. Weather data is transmitted from the computer server through a pager network to the receivers hourly. Data includes temperature, wind speed, relative humidity, and solar radiation data. The WR-7 uses this information to estimate ET accumulation on an hourly cycle, and processes it into a running ET balance.

The WR-7 does not include on-site sensors or gages. A tipping bucket type rain gage is available as an optional add-on component to the receiver. With or with-

out the gauge, the receiver accounts for local rainfall which affects the root zone soil moisture balance. In addition, the receiver includes a wind factor adjustment which may be set to compensate for significant variance in on-site wind conditions versus the conditions measured at the weather station. The current retail price for the WR-7 is \$485, and accessory prices are summarized in the table below. The existence of an ongoing service fee is dependant on the service provider, as discussed later.

A growing network of Weather Reach System Providers exists throughout the U.S., covering areas in several northeastern, southwestern and Rocky Mountain states. For a covered area, data from multiple weather stations are received, processed, and then transmitted by a single provider. The WR-7 receivers are programmed to receive data from the appropriate weather station based on a weather region code. The data are transmitted by the provider using a Motorola® Flex® paging system.

Once the WR-7 receives the data and calculates ET, one of four modes are available for the receiver to communicate with the irrigation controller. These include: ET Enable, ET Trigger, ET Pulse, and RS-232. Selection of the appropriate mode is dependant on the irrigation controller being used.

WR-7 Accessories Prices

Component	Model No.	Price
Plug-in Transformer	WR-PS	\$25
External Antenna	WR-ANT	\$32
Outdoor Enclosure	WR-OE	\$98
Pronamic Rain Gage	WR-PRG	\$85

Residential irrigation controllers typically require use of either the ET Enable or the ET Trigger modes. The ET Pulse and RS-232 modes are compatible with commercial type controllers, and their communication processes are not discussed herein.

The ET Enable mode functions by interrupting the common wire circuit from the irrigation controller to the automatic irrigation control valves. The WR-7 allows for irrigation by closing this circuit. This mode is used to control most irrigation controllers that use a common circuit to provide power to the system.

In the ET Trigger mode, the WR-7 closes a switch contact to trigger irrigation when ET accumulates to the programmed threshold. The switch duration is programmable to accommodate the controller. The controller recognizes the momentary switch closure as a signal to irrigate. For this mode, the controller should also have day and time condition settings that must also be met to start an irrigation cycle.

Regardless of the receiver to controller mode used, the controller is programmed based on a plant root zone moisture depletion and ET threshold balance concept. This balance is maintained based on ET minus effective rainfall. The user programs one of four settings to define effective rainfall. Effective rain is based on the soil moisture intake rate and soil moisture holding capacities.

The controller schedule is set to irrigate every day, unless certain days are to be excluded for a variety of reasons. The receiver then signals the controller when the ET threshold is reached, and the prescribed irrigation amounts are applied to replenish the root zone depletion. The

receiver includes two programs so that two ET thresholds and landscape adjustment percentages may be used. This provides for different stations to be scheduled separately to meet the needs associated with varying plant types and conditions. There are user-defined settings to define effective rainfall.

As discussed above, the WR-7 simply turns the irrigation controller on when a specified demand is reached which coincides with a specified depletion. The irrigation controller's features allow for programming to satisfy the demands dictated by the landscape features. Specifically, the controller schedule should be developed based on application rates and plant types, and soil, slope, and shade conditions. Hence, the ability of the system to irrigate all stations efficiently and minimize run off is very much dependent on the controller used.

The WR-7 is a small (4.8"X5.25"X1.5") plastic cabinet designed for indoor installation. A lockable fiberglass outdoor enclosure is available as an accessory. In the event a power supply is not available from the existing controller, an optional power transformer is available. Irrisoft requires installation by a professional irrigation system specialist, and they market their products through specialty irrigation product suppliers.

As mentioned above, potential ongoing costs are dependent on the service provider for a given area. Irrisoft reports that the split between existing public and private providers is approximately 50 percent. Public providers typically absorb the cost of the weather stations, computer server and software, and paging system, and there is no ongoing user cost. Private providers pass on these costs to their users, and the two providers inter-

viewed for this review reported typical residential rates in the range of \$100 to \$350. Existing public providers include the City of Denver, Colorado Water Department, the Northern Colorado Water Conservancy District, Southern Nevada Water Authority, the Utah Division of Water Resources, and Irvine Ranch Water District, in Orange County, California.

During recent years, numerous demonstration projects using the Irrisoft System have been initiated. The overall results from these ongoing projects indicate sufficient water savings can be achieved with the system and that the system functions well in many areas.

A sampling of these projects is provided in the table below. In addition, Irrisoft has provided a list of about 25 municipal and institutional entities currently using their product in residential and commercial applications.

Depending on the variance between on-site conditions and those measured at the weather station being used, the use of a rain gage, and the accuracy of the controller programming; the WR-7 should provide most users with relatively accurate real-time weather based irrigation scheduling system.

Summary of Irrisoft Demonstration Projects

Sponsor	No. of Test sites
Denver Water Department	12
Utah Division of Water Resources	8
Northern Colorado Water Conservancy District	10
Southern Nevada Water Authority	10
Terra Weather Broadcasting, Houston, Texas	25

Product Features Matrix

Manufacturer	Advantages	Disadvantages
Aqua Conserve	<ul style="list-style-type: none"> • Documented track record • Low controller cost • No ongoing service cost • Stand alone - Not dependant on communication network 	<ul style="list-style-type: none"> • Schedules must be programmed manually • Runoff may result if runtime and soak cycles are not programmed correctly • Rain sensor extra • Adequacy of 16 historical ET curves unknown • Uses limited amount of weather data to estimate plant irrigation needs • Does not account for amount of local rainfall in irrigation schedule adjustment • Instructions do not account for drip or native plants
Weathermatic	<ul style="list-style-type: none"> • Documented pilot testing • Fully automatic scheduling • Moderate controller cost • Rain sensor included • Stand alone - Not dependant on communication network 	<ul style="list-style-type: none"> • Not available yet • Uses limited amount of weather data to estimate plant irrigation need • Does not account for amount of local rainfall in irrigation schedule adjustment
WeatherSet	<ul style="list-style-type: none"> • Fully automatic or manual scheduling • Low controller cost • No ongoing service cost • Rain sensor included • Stand alone - Not dependant on communication network 	<ul style="list-style-type: none"> • Limited track record • Solar sensor needs to be cleaned periodically. • Limited ability to select application rate. • Total runtime may be excessive for locations where multiple cycle and soak is required
AccuWater	<ul style="list-style-type: none"> • Fully automatic scheduling • Includes rain gauge • Computer interface • Water use info available to others via internet 	<ul style="list-style-type: none"> • Not available yet • Limited Track Record and planned availability in US locations limited • High controller cost • Ongoing service cost • Requires high speed internet • Not available yet
ET Water Systems	<ul style="list-style-type: none"> • Fully automatic scheduling • Computer interface • Low controller cost (Planned) • Water use info available to others via internet • Can suspend irrigation due to wind or temperature 	<ul style="list-style-type: none"> • Limited track record • Ongoing service cost • Rain sensor extra
HydroPoint	<ul style="list-style-type: none"> • Documented track record • Fully automatic scheduling 	<ul style="list-style-type: none"> • High controller cost • Ongoing service cost • Rain sensor extra • Does not account for amount of local rainfall in irrigation schedule adjustment
Irrisoft	<ul style="list-style-type: none"> • Documented track record • Ability to control unlimited number of stations • Can suspend irrigation due to wind or temperature 	<ul style="list-style-type: none"> • Rain sensor extra • High receiver cost • Potential ongoing service cost

Weather Based Residential Irrigation Technologies - Summary of Features

Company Name	Aqua Conserve	Weathermatic	WeatherSet Company	AccuWater	ET Water Systems	HydroPoint Data Systems	Irrisoft Inc.
Phone	(909) 352-3891	(972) 278-6131	(818) 993-1449	(512) 231-8696	(415) 388-4887	(707) 769-9696	(455) 755-0400
Contact Person	Gary Bailey	Brodie Bruner	Andrew Davis	Tom Watson	Bruce Cardinal	Chris Manchuck	Steven Moore
Web Page	www.aquaconserve.com	www.weathermatic.com	www.weatherset.com	www.accuwater.com	www.etwater.com	www.hydropoint.com	www.weatherreach.com
Number of Residential Models	7	1	7	4	1	1	1
Date of Product Availability	New Model-July 2003	Planned November 2004	New Model-September 2003	Planned May 2004	Planned September 2004	New Model-June 2004	July 2002
Method of Operation							
Basis for Schedule	Historical Data	On-site temperature sensor and solar radiation estimated based on geographic location	Solar sensor	Accuwater & weather station data managed by centralized computer server	Public & ETWS weather station data managed by centralized computer server	Public weather station data managed by centralized computer server	Public & private weather station data managed by centralized computer server
On-Site Sensors	One-Site Sensors	On-site temperature sensor and solar radiation estimated based on geographic location	Solar sensor	Accuwater & weather station data managed by centralized computer server	Public & ETWS weather station data managed by centralized computer server	Public weather station data managed by centralized computer server	Public & private weather station data managed by centralized computer server
Remote Weather Station(s)	16 preprogrammed ET curves with on-site temperature sensor	4-16 (by 4 Sta modules)	8-24	16	12 plus master	12	12
Modeling Software							
Weather Data Source							
Product Features							
Replacement Controller or Add-on to Existing	Both	Replacement	Replacement	Replacement	Replacement	Replacement	Add-on
Number of Station Terminals	6-14	4-16 (by 4 Sta modules)	8-24	16	12 plus master	12	Dependent on Controller
One Station Operates Master Valve or Pump	•	•	•	•	•	•	Dependent on Controller
User Review of Irrigation History	•	•	•	•	•	•	•
Non-volatile Memory	•	•	•	•	•	•	•
Station Circuit Current Rating (Amperes)	1.0	1.5	0.75 and 1.5	0.3	Not Reported	1.0	Not Applicable
Accepts All Common Wire Sizes	•	•	•	•	•	•	•
Outdoor Installation	• (ET-8b & 12b)	•	• (1)	• (1)	•	• (1)	• (1)
On-site Rain Sensor	• (1)	•	•	•	•	• (1)	• (1)
On-site Rain Gauge	• (1)	•	•	•	•	• (1)	• (1)
Rain Shut-off	•	• (1)	•	•	•	• (1)	•
High Wind Shut-off	•	•	•	•	•	• (1)	•
Freeze Shut-off	•	•	•	•	•	• (1)	•
Scheduling Features							
User Defined Non-Irrigation Days	•	•	•	•	•	•	•
Operable in "Clock" mode	•	•	•	•	•	•	•
Variable Run Times	•	•	•	•	•	•	•
Provides Review of Recent Irrigation Information	•	•	•	•	•	•	•
Provides Review of Current Weather Information	•	•	•	•	•	•	•
Base Irrigation Schedule Required	•	•	•	•	•	•	•
Adjusts for Multiple Starts Automatically	•	•	•	•	•	•	•
Runs Concurrent Stations	•	•	•	•	•	•	•
Number of Multiple Starts Per Station	16	Unlimited	24	Unlimited	Unlimited	Up to 64 cycles	Up to 64 cycles
+/- Percent Irrigation Adjust Feature	• (2)	•	• (2)	•	•	•	•
Application Rate Setting	•	•	•	•	•	•	•
Root Depth Setting	•	•	•	•	•	•	•
Plant Type Setting	•	•	•	•	•	•	•
Soil Type Setting	•	•	•	•	•	•	•
Slope Factor Setting	•	•	•	•	•	•	•
Shade Factor Setting	•	•	•	•	•	•	•
Irrigation Uniformity or Efficiency Setting	•	•	•	•	•	•	•
Product Support and Warranty							
Warranty	3 years	2 years	3 years	1 year	3 years	3 years	1 Year
Support	Service Technicians	Telephone	Telephone	Telephone	Telephone	Telephone	Telephone
	Internet Site	Internet Site	Internet Site	Internet Site	Internet Site	Internet Site	Internet Site
	Local Distributors	Local Distributors	Local Distributors	Local Distributors	Local Distributors	Local Distributors	Local Distributors
Installation and Maintenance Requirements							
Professional Installation & Programming Required	•	•	•	•	•	•	•
Ongoing Maintenance Required	•	•	•	•	•	•	•
Clock Battery Replacement Required	•	•	•	•	•	•	•
Cost							
Product Cost (Listed Retail Prices)	\$99-\$459	\$349 (includes installation)	\$170-\$230	\$400-\$600	\$299 (includes 1 year of service)	\$480 (includes 2 years of service)	\$485
Annual Service Cost	None	None	None	\$180	\$48	\$48	None or \$100-\$350

Stand-alone units which utilize preprogrammed historic ET data and or on-site weather sensors to automate irrigation scheduling
Units which automate irrigation scheduling based on data from local weather stations

1 - Optional add-on feature not included in base controller price

2 - Rate prescribed by spray or rotor irrigation type only (no flow rate or drip setting)