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# Initial Evaluation of Smart Irrigation Controllers: Year Two (2009) Results


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Texas Water Resources Institute
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TR 364

# INITIAL EVALUATION OF SMART IRRIGATION CONTROLLERS:

## YEAR TWO (2009) RESULTS[1]

By

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**A Report Prepared for Task 2**
**of the Rio Grande Basin Initiative**

**Irrigation Technology Center**
**Texas AgriLIFE Extension Service**

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## SUMMARY

A smart controller testing facility was established by the Irrigation Technology Center at Texas A&M University in College Station in 2008. A two-year testing program was initiated in order to evaluate smart controller testing methodology needed to determine their performance and reliability under Texas conditions from an “end-user” point of view. The “end-user” is considered to be the landscape or irrigation professional (such as a Licensed Irrigator in Texas) installing the controller. During the first year (2008), six (6) controllers were evaluated over a 60-day period. Details were provided by Swanson and Fipps (2008). This report details the results of the second year (2009) evaluations.

Four additional controllers were provided by manufacturers for the 2009 evaluations, bringing the total number of controllers evaluated to 10, and the evaluation period was extended to 13 weeks. As in the first year, the 10 controllers were programed for College Station, Texas using a modified version of the virtual landscape as defined in the IA (Irrigation Association) SWAT (Smart Water Applicator Technologies) 7th draft testing protocol.

Programing the controllers according to these virtual landscapes proved to be problematical, as most of the controllers did not allow the direct programing of all of the parameters needed to define the virtual landscape and irrigation system. In addition, it was impossible to see the actual values that some controllers used for each parameter or to determine how closely these followed the values of the virtual landscape.

The 2009 results showed some improvement in controller performance over Year One results. There were no software or hardware problems observed. Only one controller had communication problems which were reported to the manufacturer’s representative but not corrected during the study.

### Seasonal Irrigation Amounts

- When looking at total seasonal irrigation amounts for the entire landscape, two (2) controllers were within the recommendations of the TexasET Network, six (6) were within 50% of ETo, and five (5) were with 80% of a simple ETc model (ETo x Kc, neglecting rainfall).

### Individual Station (zone) Irrigation Amounts

- The results showed considerable inconsistency by the 10 controllers, with total irrigation volumes within the same station (or zone) ranging from 3 to 5 times as much water from controller to controller.

- When compared to a simple ETc model (ETo x Kc; neglecting rainfall), irrigation amounts exceeded ETc 37% of the time even though over 14 inches of rain occurred during the study.

- Controllers produced irrigation amounts exceeding ETo 20% of the time. About 14% of the irrigation amounts were within the recommendations of the TexasET Network and Website (http://texaset.tamu.edu).

- Based on the 2009 performance, controllers with onsite sensors for determining water requirements irrigated much closer or within the recommendations of TexasET. As in the First Year results, controllers that received ET/ETo and rain information remotely irrigated much higher than the recommendations.

Such high irrigation amounts are hypothesized to be related to the source and values for the ETo used by the controllers, default values used to define landscape parameters, and/or the methodologies used to account for rainfall. We have used the results of the past two years of evaluations to establish updated protocols for future studies.

# INTRODUCTION

The term *smart irrigation controller* is commonly used to refer to various types of controllers that have the capability to calculate and implement irrigation schedules automatically and without human intervention. Ideally, smart controllers are designed to use site specific information to produce irrigation schedules that closely match the day-to-day water use of plants and landscapes. In recent years, manufacturers have introduced a new generation of smart controllers which are being promoted for use in both residential and commercial landscape applications. The Irrigation Association (IA) has reported that in some studies, these controllers have reduced water usage by as much as 16% when compared to conventional controllers.

However, many questions exist about the performance, dependability and water savings benefits of smart controllers. Of particular concern in Texas is the complication imposed by rainfall. Average rainfall in the State varies from 56 inches in the southeast to less than eight inches in the western desert. In much of the State, significant rainfall commonly occurs during the primary landscape irrigation seasons. Some Texas cities and water purveyors are now mandating smart controllers. If these controllers are to become requirements across the state, then it is important that they be evaluated formally under Texas conditions.

# CLASSIFICATION OF SMART CONTROLLERS

Smart controllers may be defined as irrigation system controllers that determine runtimes for individual stations (or "zones") based on historic or real-time ETo and/or additional site specific data. We classify smart controllers into four (4) types (see Table 1): Historic ET, Sensor-based, ET, and Central Control.

Many controllers use ETo (potential evapotranspiration) as a basis for computing irrigation schedules in combination with a root-zone water balance. Various methods, climatic data and site factors are used to calculate this water balance. The parameters most commonly used include:

- ET (actual plant evapotranspiration)
- Rainfall
- Site properties (soil texture, root zone depth, water holding capacity)
- MAD (managed allowable depletion)

The IA SWAT committee has proposed an equation for calculating this water balance. For more information, see the IA's website: http://irrigation.org.

| Table 1. Classification of smart controllers by the basis of the method used in the calculation of irrigation runtimes. | |
|---|---|
| Historic ET | Uses historical ET data from a table stored in the controller |
| Sensor-Based | Uses one or more sensors (usually temperature and/or solar radiation) to adjust or to calculate ETo using an approximate method |
| ET | Real-time ETo (usually determined using a form of the Penman equation) is transmitted to the controller daily. Alternatively, the runtimes are calculated centrally based on ETo and transmitted to the controller. |
| On-Site Weather Station (Central Control) | A controller or a computer which is connected to an on-site weather station equipped with senors that record temperature, relative humidity (or dew point temperature) wind speed and solar radiation for use in calculating ETo with a form of the Penman equation. |

# MATERIALS AND METHODS

## Testing Equipment and Procedures

Two smart controller testing facilities have been established by the ITC at Texas A&M University in College Station: an indoor lab for testing ET-type controllers and an outdoor lab for Sensor-based controllers. Basically, the controllers are connected to a data logger which records the start and stop times for each irrigation event and station (or zone). This information is transferred to a database and used to determine total runtime and irrigation volume for each irrigation event. The data acquisition and analysis process is illustrated Figure A-1 . Additional information and photographs of the testing facilities are provided in the Appendix.

## Smart Controllers

Ten (10) controllers were provided by manufacturers for the Year Two evaluations. The specific manufacturers and products are not identified in this report. Each controller was assigned an ID for reporting purposes. Table 2 lists each controller's classification, communication method and on-site sensors, as applicable. The controllers were grouped by type for testing purposes. The ET Controllers (A-E) were tested indoors, and the Sensor-based Controllers F-J were tested outdoors.

Table 2. The testing ID, type, communication method, sensors, and SWAT test results of the controllers evaluated in this study.

| Controller ID | Type | Communication Method | Sensors Utilized | SWAT Irrigation Adequacy | SWAT Irrigation Excess |
|---|---|---|---|---|---|
| A | ET | Pager | None | NA | NA |
| B | ET | Internet | None | NA | NA |
| C | ET | Pager | None | 100% | 1.5% |
| D | ET | Pager | None | 100% | 0% |
| E | ET | Pager | None | 100% | 0% |
| F | Sensor-Based | None | Rain, Pyranometer | NA | NA |
| G | Sensor-Based | None | Rain, Temperature | 100% | 0.4% |
| H | Sensor-Based | None | Rain, Temperature, Pyranometer | 100% | 0.5% |
| I | Sensor-Based | None | Rain , Temperature, Pyranometer | 100% | 7.55% |
| J | Sensor-Based | None | Rain, Temperature, Pyranometer | 100% | 1.5 |

Definition of Stations (Zones) for Testing

Each controller was assigned six stations, each station representing a virtual landscaped zone. These zones were based on those proposed in the SWAT testing protocol (Table 3). However, we made one change in the virtual landscape set-up. Since we do not recommend that schedules be adjusted for the DU (distribution uniformity), the efficiency were set to 100% where allowed by the controller.

Programing the smart controllers according to these virtual landscapes proved to be problematical, as not all of the controllers had the options needed to directly program all of the required parameters to describe the landscape and/or irrigation system. Table 4 shows the parameters which could be selected for each controller. In addition, it was impossible to see the actual values that some controllers used for each parameter or to determine how closely these followed the values of the virtual landscape.

One example of programming difficulty was entering soil type. Six different soil types are included in the virtual landscape; however only two of the 10 controllers have all six soil types as input options. Only five of the 10 controllers in the study allowed the user to enter the root zone depth (soil depth). Another example is entering landscapes plant information. Only five of the controllers provide the user the ability to see and adjust the actual coefficient (i.e., 0.6, 0.8, etc) that corresponds to the selected plant material

(i.e., fescue, cool season grass, etc.).
Thus, we programmed the controllers to match the virtual landscape as closely as was possible. Manufacturers were given the opportunity to review the programming, which three did.

(Continued on next page)

Table 3. The virtual landscape as defined in the 7th draft SWAT testing protocol.

| | Station 1 | Station 2 | Station 3 | Station 4 | Station 5 | Station 6 |
|---|---|---|---|---|---|---|
| **Soil Texture** | Loam | Silty Clay | Loamy Sand | Sandy Loam | Clay Loam | Clay |
| **Exposure** | 75% Shade | Full Sun | Full Sun | 50% Shade | Full Sun | Full Sun |
| **Root Zone Working Water Storage (in)** | 0.85 | 0.55 | 0.90 | 2.00 | 2.25 | 0.55 |
| **Vegetation** | Fescue | Bermuda | Ground Cover | Woody Shrubs | Trees & Ground Cover | Bermuda |
| **Crop Coefficient (Kc)** | 0.8 | 0.6 | N/A | N/A | N/A | 0.6 |
| **Landscape Coefficient (KL)** | N/A | N/A | 0.55 | 0.40 | 0.61 | N/A |
| **Precipitation Rate (in/hr)** | 1.60 | 1.60 | 1.40 | 1.40 | 0.20 | 0.35 |

Table 4. The parameters which could be set in each controller directly identified by the letter "x."

| Controller | Soil Type[4] | Root Zone Depth[4] | MAD[4] | Sun Exposure | Plant Type | Precipitation Rate | Zip Code or Location |
|---|---|---|---|---|---|---|---|
| A | X | X | X | X | X | X | X |
| B[1] | X | X | X | X | X | X | X |
| C | X | X | X | X | X | X | X |
| D[2] | - | - | - | | X | X | X |
| E | X | X | X | X | X | X | X |
| F | | | | | X | X | |
| G | X | | | | X | X | X |
| H | X | | | X | X | X | |
| I[3] | | | | | | | X |
| J | X | X | | X | X | X | |

[1]Controller had soil depth, but not root zone depth
[2] Controller required the direct entry of allowable soil water depletion (i.e. "root zone working water storage")
[3] Controller was programmed for runtime and frequency at peak water demand (July).
[4]Soil type and root zone depth along with MAD are needed to define "root zone working water storage"

## Testing Period

The controllers were set up and allowed to run for a 13 week (91 day) period from July 20 to October 18, 2009.

## ETo and Recommended Irrigation

ETo was computed from weather parameters measured at the Texas A&M University Golf Course in College Station, TX. The weather parameters were measured with a standard agricultural weather station which records temperature, solar radiation, wind and relative humidity. ETo was computed using the standardized Penman-Monteith method. ETo and Rainfall rates during the evaluation period are given in Table 10.

*TexasET and the Plant Water Requirement Calculator*

In this report, smart controllers irrigation results are compared to the recommendations of the TexasET Network and Website generated using the Landscape Plant Water Requirement Calculator (http://TexasET.tamu.edu ) based on a weekly water balance. This is the method that is used in the weekly irrigation recommendations generated by TexasET for users that sign-up for automatic emails. The calculation uses the standard equation:

ETc = (ETo x Kc x Af) - Re (Equation 1)

where: ETc = irrigation requirement
ETo = reference evapotranspiration
Kc = crop coefficient
Af = adjustment factor
Re = effective rainfall

Recommended Kc for warm season turf is 0.6 and cool season 0.8. Due to the lack of scientifically derived crop coefficients for most landscape plants, we suggest that users classify plants into one of three categories based on their need for or ability to survive with frequent watering, occasional watering and natural rainfall. Suggested crop coefficients for each are shown in Table 5.

In addition to using a Plant Coefficient, users have the option of applying an Adjustment Factor. This can be used to adjust the crop coefficient for various site specific factors such as microclimates, allowable stress, or desired plant quality. For most home sites, a Normal Adjustment Factor (0.6) is recommended in order to promote water conservation, while an adjustment factor of 1.0 is recommended for sports athletic turf. Table 6 gives the adjustment factor in terms of a plant quality factor. Effective rainfall was calculated using the relationships shown in Table 7.

| Table 5. Landscape Plant Water Requirements Calculator Coefficients | | |
|---|---|---|
| **Plant Coefficients** | | **Plant Types** |
| **Warm Season Turf** | 0.6 | Bermuda, St Augustine, Buffalo, Zoysia, etc. |
| **Cool Season Turf** | 0.8 | Fescue, Rye, etc. |
| **Frequent Watering** | 0.8 | Annual Flowers |
| **Occasional Watering** | 0.5 | Perennial Flowers, Groundcover, Tender Woody Shrubs and Vines |
| **Natural Rainfall** | 0.3 | Tough Woody Shrubs and Vines and non-fruit Trees |

| Table 6. Adjustment Factors in terms of "Plant Quality Factors." | |
|---|---|
| Maximum | 1.0 |
| High | 0.8 |
| Normal | 0.6 |
| Low | 0.5 |
| Minimum | 0.4 |

| Table 7. TexasET Effective Rainfall Calculator | |
|---|---|
| **Rainfall Increment** | **% Effective** |
| 0.0" to 0.1" | 0% |
| 0.1" to 1.0" | 100% |
| 1.0" to 2.0" | 67% |
| Greater than 2" | 0% |

For the Smart Controller Evaluation Program, a weekly irrigation recommendation was produced using equation (1) following the methodology discussed above. In the Year One (2008) study, an adjustment factor (Af) of 1.0 was used. Here, a range of TexasET irrigation recommendations is reported corresponding to an adjustment factor (Af) ranging from 0.6 to 1.0.

## RESULTS AND DISCUSSION

Results from the Year Two evaluations are summarized in Table 8 which shows the irrigation volumes for each controller and station (zone) during the evaluation period. In Table 9, total irrigation volumes by controller over the entire evaluation period are shown in inches and as a percentage of ETo and ETc.

When looking at total seasonal irrigation amounts for the entire landscape, two (2) controllers were within the recommendations of the TexasET Network, six (6) were within 50% of ETo, and five (5) were with 80% of a simple ETc model (ETo x Kc, neglecting rainfall).

Ideally, all controllers would produce about the same irrigation amount for the same station (zone). However, there was significant variation between the irrigation amounts, ranging from 3 to 5 times as much water for the same station produced by these controllers.

The ET Controllers produced irrigation amounts that exceeded ETo 20% of the time. This is surprising since ETo is defined as the potential water requirements of a cool season reference crop, and most landscape plants will require less water than ETo. However, this is actually an improvement over Year One results where the ET Controllers produced irrigation amounts exceeding ETo 58% of the time. Possible explanations for exceeding ETo is the source and actual values that each controller uses for ETo and rainfall. Due to rainfall, no irrigation was technically needed for seven (7) weeks during the testing period.

Also listed in Table 8 are the irrigation volumes computed using a simple ETc model (ETo x Kc) neglecting rainfall. We found that 37% of the controllers had irrigation volumes that exceeded this amount, indicating incorrect values used by these controllers for ETo and Kc. Also, this data also indicates problems by several of the controller's in properly handling rainfall as well, since 14 inches of rain occurred during the evaluation period (Table 10).

Only 13.6% of the irrigation amounts were within the range recommended by TexasET, with the remainder significantly higher. The ET Controllers exceeded recommended irrigation amounts 97% of the time (versus 100% of the time in the Year One study), applying on average 6.31inches more water. The sensor-based controllers exceeded the recommended amount 76% of the time (unchanged from the Year One results) applying on average 2.64 inches (1.88 inches in the Year One study) more water.

Table 8. Summary of Second Evaluation Results, July 20-Oct 18, 2009 for ET Controllers (A-E) and Sensor-based Controllers (F-J). Also shown are the total ETo and Rainfall recorded during the evaluation period.

| | **Station 1** | **Station 2** | **Station 3** | **Station 4** | **Station 5** | **Station 6** |
|---|---|---|---|---|---|---|
| **Plant Type** | Cool Season | Warm Season | Ground Cover | Shrubs | Trees | Warm Season |
| A (discontinued) | 13.42 | 11.72 | 15.82 | 8.82 | 17.05 | 11.74 |
| B | 4.93 | 5.02 | 13.13 | 10.48 | 4.47 | 5.37 |
| C | 7.20 | 7.46 | 7.84 | 5.88 | 3.64 | 6.86 |
| D | 15.19 | 15.19 | 15.40 | 15.40 | 7.60 | 15.05 |
| E | 7.76 | 10.86 | 10.09 | 6.82 | 11.89 | 13.79 |
| F | 7.34 | 7.02 | 10.38 | 5.41 | .77 | 1.53 |
| G | 8.88 | 6.67 | 5.56 | 5.56 | 8.80 | 7.70 |
| H | 2.63 | 3.40 | 4.66 | 2.67 | 4.15 | 4.10 |
| I | 12.20 | 9.21 | 7.57 | 4.51 | 9.18 | 9.08 |
| J | 4.89 | 5.65 | 5.60 | NA[1] | 4.69 | 5.76 |
| TexasET Recommendation[2] | 3.56-6.52 | 2.59-4.54 | 2.11-3.73 | 2.11-3.73 | 1.13-2.11 | 2.59-4.54 |
| ETc (ETo x Kc)[3] | 12.06 | 9.05 | 8.29 | 6.03 | 9.20 | 9.05 |
| **ETo[4]** | 15.08 inches | | | | | |
| **Rainfall** | 14.31 inches | | | | | |

[1] Controller J, Station 5 experienced a hardware malfunction during the study, as a results this data set was omitted

[2] Total Weekly Calculations of Landscape Plant Water Requirement Calculator, TexasET

[3] Rainfall is not included in calculation

[4] Total ETo calculated using the standardized Penmen-Monteith method using weather data collected at the the Texas A&M University Golf Course, College Station, Texas.

| Table 9. Comparison of Total Applied Volumes (inches) of Each Controller to Plant Water Requirements and ETo. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Total** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| **Irrigation Applied, in** | 78.6 | 43.4 | 38.9 | 83.8 | 61.2 | 32.5 | 43.2 | 21.6 | 51.8 | 26.6 |
| **% ETc** | 146% | 81% | 72% | 156% | 114% | 61% | 80% | 40% | 96% | 50% |
| **% ETo** | 87% | 48% | 43% | 93% | 68% | 36% | 48% | 24% | 57% | 35% |
| **TexasET Rec.** | 14.1 - 25.2 | | | | | | | | | |
| **ETc (ETo x Kc)**[1] | 53.7 | | | | | | | | | |
| **ETo** | 90.5 | | | | | | | | | |
| **Rainfall** | 14.3 | | | | | | | | | |

[1] effective rainfall not subtracted

## CONCLUSIONS AND FUTURE PLANS

Over the past four years since we started our "end-user" evaluation of smart controllers, we have seen improvement in their performance. The communication and software failures that were evident in our field surveys conducted in San Antonio in 2006 (Fipps, 2008) are no longer a problems. In the past two years of bench tesiting, we have seen some reduction in excessive irrigation charactaristic of a few controllers.

Our emphais is on an "end-user" evaluation, that is to develop a program that will be able to evaluate controller proferomance as it is installed in the field. The "end-user" is considered as the landscape or irrigation contractor (such as a licensed irrigator in Texas) who installs and programs the controller.

For the 2010 evaluations, we will be making changes in this program. Performance will be tracked over a full active growing season, March through October for South Central Texas. In addition a new virtual landscape will be utilized, one that more accurately deplicts typical Texas landscapes. In accordance with new State of Texas rules and regulations, a rainsensor will be added to all controllers which do not already utilize one. We will also be examing the calculation methods for effective rainfall and the soil water balance and how these affect irrigation scheduling and volumes.

# Appendix A

Figure A-1. System Set-Up and Data Flow

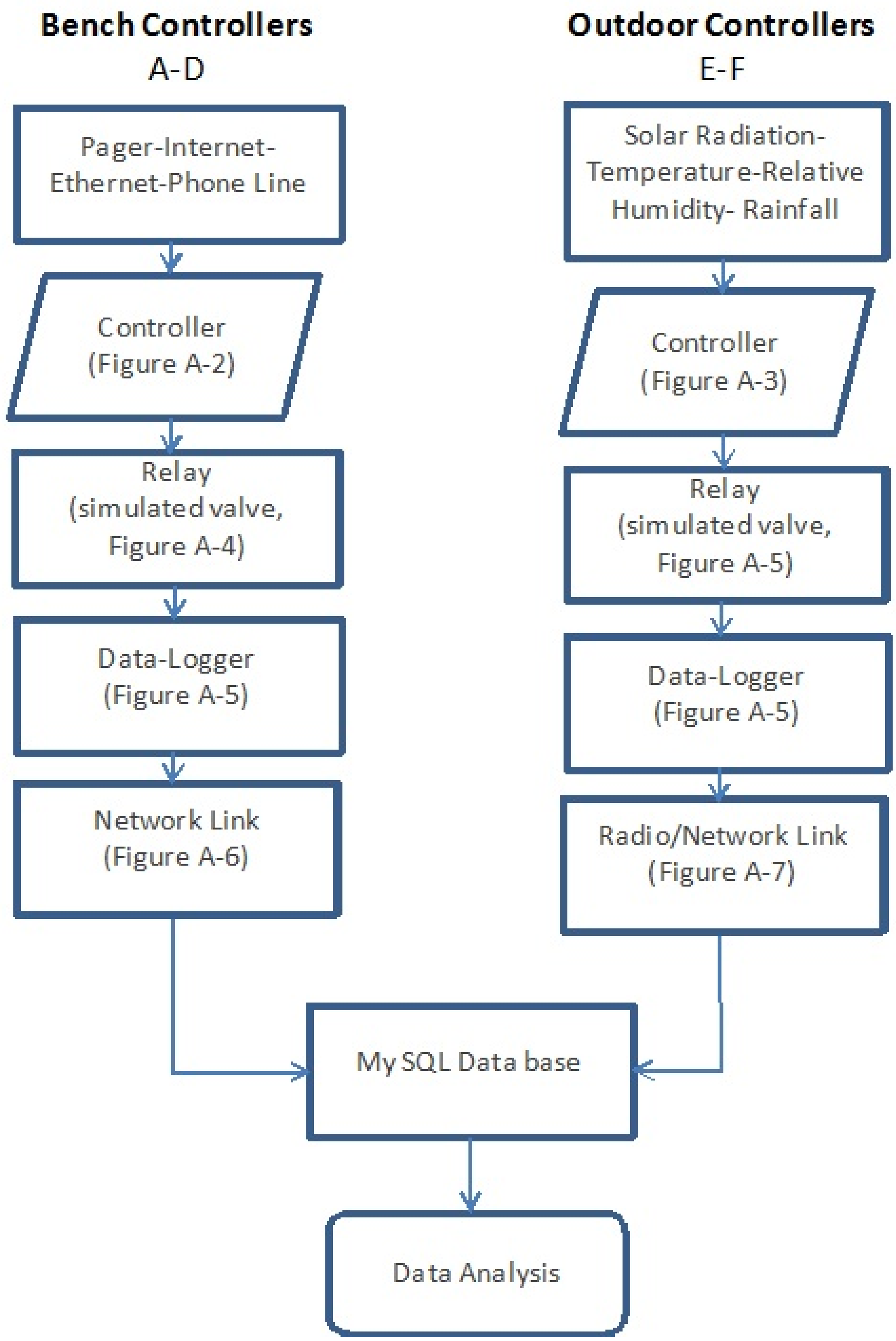

Figure A-2. Bench Tested Controllers

Figure A-3. Outdoor Tested Controllers

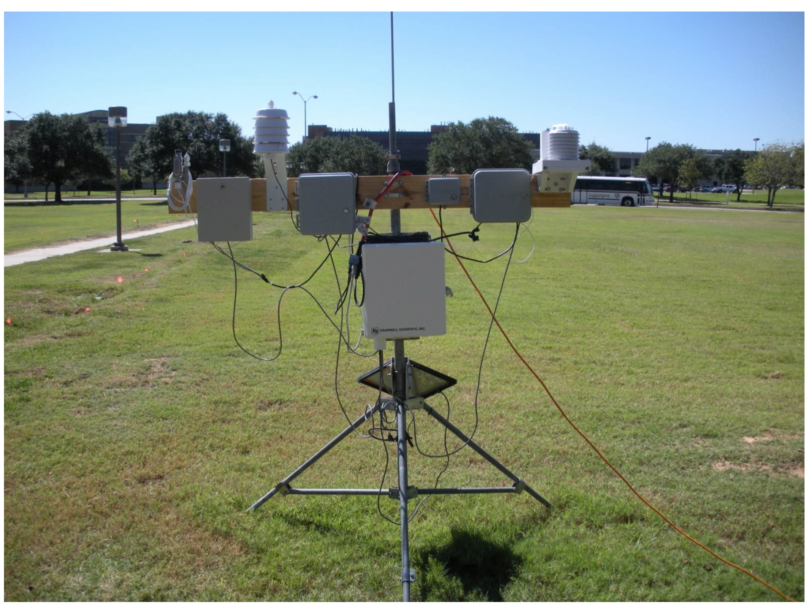

Figure A-4. Outdoor Tested Controller (cont)


Figure A-5. Relays

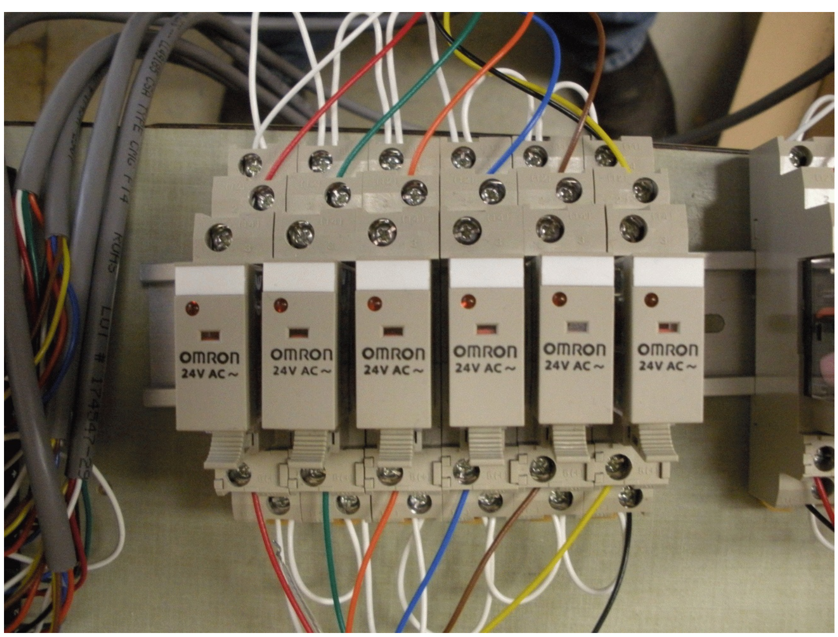

Figure A-6. Datalogger

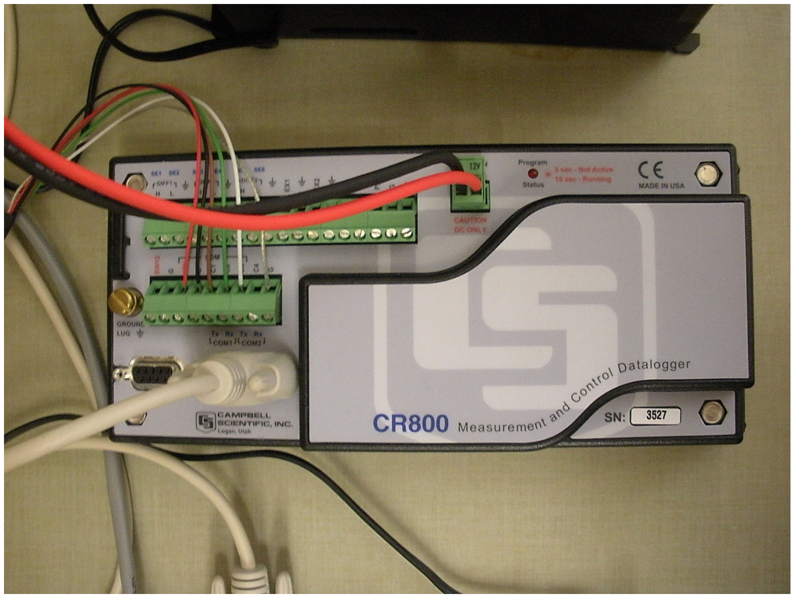


Figure A-7. Network Link

Figure A-8. Radio/Network Link

# Appendix B

Table 10. Daily ETo and Rainfall, College Station, Texas, 91 Days

| Date | ETo | Rain | | Date | ETo | Rain |
|---|---|---|---|---|---|---|
| 20-July | .21 | 1.65 | | 15-August | .22 | 0 |
| 21-July | .24 | 0.01 | | 16-August | .2 | 0 |
| 22-July | .21 | 0 | | 17-August | .19 | 0 |
| 23-July | .16 | 0 | | 18-August | .18 | 0 |
| 24-July | .19 | 0 | | 19-August | .23 | 0 |
| 25-July | .26 | 0 | | 20-August | .26 | 0 |
| 26-July | .29 | 0 | | 21-August | .21 | 0 |
| 27-July | .27 | 0 | | 22-August | .19 | 0 |
| 28-July | .29 | 0 | | 23-August | .20 | 0 |
| 29-July | .25 | 0 | | 24-August | .23 | 0 |
| 30-July | .16 | 1.43 | | 25-August | .20 | 0.11 |
| 31-July | .12 | 0.30 | | 26-August | .17 | 0.06 |
| 1-August | .28 | 0 | | 27-August | .17 | 0.01 |
| 2-August | .13 | 0 | | 28-August | .21 | 0.02 |
| 3-August | .28 | 0 | | 29-August | .17 | 0 |
| 4-August | .20 | 0 | | 30-August | .19 | 0 |
| 5-August | .20 | 0 | | 31-August | .18 | 0 |
| 6-August | .24 | 0 | | 1-Sept | .16 | 0 |
| 7-August | .27 | 0 | | 2-Sept | .19 | 0 |
| 8-August | .27 | 0 | | 3-Sept | .22 | 0 |
| 9-August | .17 | 0 | | 4-Sept | .10 | 0.01 |
| 10-August | .24 | 0 | | 5-Sept | .13 | 0 |
| 11-August | .24 | 0 | | 6-Sept | .19 | 0 |
| 12-August | .21 | 0 | | 7-Sept | .19 | 0 |
| 13-August | .19 | 0 | | 8-Sept | .19 | 0 |
| 14-August | .22 | 0 | | 9-Sept | .08 | 0.07 |

| Table 10(cont.) Daily ETo and Rainfall, College Station, Texas, 91 Days | | | | | | |
|---|---|---|---|---|---|---|
| **Date** | **ETo** | **Rain** | | **Date** | **ETo** | **Rain** |
| 10-Sept | .12 | 0.43 | | 1-October | .13 | 0 |
| 11-Sept | .08 | 1.63 | | 2-October | .19 | 0 |
| 12-Sept | .04 | 0.73 | | 3-October | .07 | 0.56 |
| 13-Sept | .13 | 0.81 | | 4-October | .06 | 0.61 |
| 14-Sept | .10 | 0.03 | | 5-October | .07 | 0 |
| 15-Sept | .10 | 0 | | 6-October | .15 | 0 |
| 16-Sept | .14 | 0 | | 7-October | .10 | 0.23 |
| 17-Sept | .09 | 0.10 | | 8-October | .20 | 0 |
| 18-Sept | .09 | 0 | | 9-October | .07 | 1.48 |
| 19-Sept | .12 | 0 | | 10-October | .04 | 0 |
| 20-Sept | .14 | 0 | | 11-October | .04 | 0.20 |
| 21-Sept | .18 | 0 | | 12-October | .05 | 0.01 |
| 22-Sept | .07 | 1.93 | | 13-October | .08 | 1.04 |
| 23-Sept | .07 | 0.20 | | 14-October | .12 | 0 |
| 24-Sept | .06 | 0.39 | | 15-October | .12 | 0 |
| 25-Sept | .12 | 0 | | 16-October | .14 | 0 |
| 26-Sept | .14 | 0 | | 17-October | .12 | 0 |
| 27-Sept | .16 | 0 | | 18-October | .11 | 0 |
| 28-Sept | .15 | 0 | | | | |
| 29-Sept | .12 | 0.21 | | **Total** | **15.08** | **14.31** |
| 30-Sept | .14 | 0 | | | | |

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