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Evaluation of Smart Irrigation Controllers: Year 2010 Results

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Texas Water Resources Institute
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EVALUATION OF SMART IRRIGATION CONTROLLERS:

YEAR 2010 RESULTS[1]

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July 15, 2011

**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 in order to evaluate their performance 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. Controllers are tested using the *Texas Virtual Landscape* which is composed of 6 different zones with varying plant materials, soil types and depths, and precipitation rates.

This report summaries the results from the 2010 evaluations. Eight controllers were evaluated over a 238 day period, from March 29 - November 22, 2010. Controller performance is analyzed for the entire evaluation period as well as seasonally (spring, summer, fall). Controller performance is evaluated by comparison to the irrigation recommendation of the TexasET Network and Website (http://texaset.tamu.edu). This year, we introduce a new evaluate methodology: *irrigation adequacy* in order to identify controllers which apply excessive and inadequate amounts of water.

Programing smart controllers for specific site conditions continues to be a problem. Only two (2) of the eight (8) controllers tested could be programmed directly with all the parameters needed to define each zone.

The 2010 results showed an increase in controller performance compared to the Year One and Year Two results. However, we continue to see controllers irrigating excessively; some irrigated in excess of ETc even though 17 inches of rainfall fell during the study.

Total Irrigation Amounts

- When looking at total irrigation amounts for the entire landscape, one (1) controller was within +/- 20% the recommendation of the TexasET Network for five (5) stations
- Two (2) controllers applied greater than a simple ETc model (ETo x Kc, neglecting rainfall) and one (1) controller was greater than ETo.

Adequacy Analysis

- No controllers were consistently able (across all 6 stations) to adequately meet the plant water requirements throughout the entire season.
- The results showed inconsistency in performance by the 8 controllers, with three (3) controllers irrigating ***excessive*** volumes and four (4) controllers irrigating ***inadequate*** volumes.
- Two (2) controllers had five (5) stations irrigate adequate amounts and two (2) controllers had four (4) stations irrigate adequate amounts.

Factors that could have caused over/under irrigation of landscapes are improper ETo calculations and insufficient accounting for rainfall. Only three (3) controllers were equipped with "tipping

bucket” type rain gauges which actually measure rainfall. Two of these were consistency among the top 3 performing controllers.

Based on 2010 performance, controllers which used onsite sensors for ET calculations irrigated closer to the recommendations of the TexasET Network than those which operate on an ET subscription. It was observed that controllers that used on site sensors more often produced inadequate irrigation amounts compared to ET subscription controllers that generally produced excessive irrigation amounts.

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.

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 “hydrozones”) 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 method used to determine plant water requirements in the calculation of runtimes.	
Historic ET	Uses historical ET data from data 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 then 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 hydrozone). 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

Eight (8) controllers were provided by manufacturers for the Year 2010 evaluations (Table 2). 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 & B) were tested indoors, and the sensor-based controllers C-H were tested outdoors.

Table 2. The controller name, type, communication method, and sensors attached of the controllers evaluated in this study. All controllers were connected to a rain shut off device unless equipped with a rain gage.

Controller ID	Controller Name	Type	Communication Method	Sensors[1]
A	ET Water	ET	Pager	None
B	Rainbird ET Manager Cartridge	ET	Pager	Tipping Bucket Rain Gauge
C	Accurate WeatherSet	Sensor Based	None	Pyranometer
D	Weathermatic Smartline	Sensor Based	None	Temperature
E	Hunter ET System	Sensor Based	None	Tipping Bucket Rain Gauge, Pyranometer, Temperature/ RH
F	Hunter Solar Sync	Sensor Based	None	Pyranometer
G	Rainbird ESP SMT	Sensor Based	None	Tipping Bucket Rain Gauge, Temperature
H	Toro Intellisense	ET	Pager	None

<u>Definition of Stations (Zones) for Testing</u>

Each controller was assigned six stations, each station representing a virtual landscaped zone (Table 3). These zones are designed to represent the range in site conditions commonly found in Texas, and provide a range in soil conditions designed to evaluate controller performance in shallow and deep root zones (and low/high water holding capacities). Since we do not recommend that schedules be adjusted for the DU (distribution uniformity), the efficiency was set to 100% if allowed by the controller.

Programing the smart controllers according to these virtual landscapes proved to be problematical, as only 2 controllers had programming options to set all the parameters defining the virtual landscape (see Table 4). In addition, it was impossible to see the actual values that two 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 root zone depth. Only five of the 8 controllers in the study allowed the user to enter the root zone depth (soil depth). Another example is entering landscapes plant information. Three of the controllers did not provide the user the ability to see and adjust the actual coefficient (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 two did. Four of the remaining manufacturers provided to us written recommendations/instructions for station programming, and one manufacturer trusted our judgement in controller programming.

Table 3. The Virtual Landscape which is representative of conditions commonly found in Texas.

	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
Plant Type	Flowers	Turf	Turf	Groundcover	Small Shrubs	Large Shrubs
Plant Coefficient (Kc)	0.8	0.6	0.6	0.5	0.5	0.3
Root Zone Depth (in)	3	4	4	6	12	20
Soil Type	Sand	Loam	Clay	Sand	Loam	Clay
MAD (%)	50	50	50	50	50	50
Adjustment Factor (Af)	1.0	0.8	0.6	0.5	0.7	0.5
Precipitation Rate (in/hr)	0.2	0.85	1.40	0.5	0.35	1.25
Slope (%)	0-1	0-1	0-1	0-1	0-1	0-1

Table 4. The parameters which the end user could set in each controller DIRECTLY identified by the letter "x."

Controller	Soil Type	Root Zone Depth	MAD	Plant Type	Adjustment Factor	Precipitation Rate	Zip Code or Location	Runtime
A	X	X	X	X	X	X	X	
B[1]	-	-	-	X	X	-	X	X
C				X				X
D	X			X	X	X	X	
E	X			X	X	X		
F[2]							X	X
G	X	X		X	X	X		
H	X	X	X	X	X	X	X	

[1] Irrigation amount was set in controller based on runtime using soil type, root zone depth, MAD and precipitation rate.
[2] Controller was programmed for runtime and frequency at peak water demand (July).

Testing Period

The controllers were set up and allowed to run for a 34 week (238 day) period from March 29 to November 22, 2010. Due to the length of the study, controller performance is reported over the entire testing period and on a seasonal basis as well. For the purposes of this study, seasons are defined as follows:

- Spring-March 29 to May 30 (62 Days),
- Summer-May 31 to August 30 (92 Days),
- Fall-August 31-November 22 (84 Days).

ETo and Recommended Irrigation

ETo was computed from weather parameters measured at the Texas A&M University Golf Course in College Station, TX which is a part of the TexasET Network (http://TexasET.tamu.edu). 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. During the evaluation period, the total ETo was 41.5 inches with a total of about 18 inches of rainfall (see Table 8).

TexasET and the Plant Water Requirement Calculator

In this report, smart controller irrigation volumes 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:

$$ETc = (ETo \times Kc \times Af) - Re \qquad \text{(Equation 1)}$$

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 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.

A weekly irrigation recommendation was produced using equation (1) following the methodology discussed above. The Af used are shown in Table 3. Effective rainfall was calculated using the relationships shown in Table 7.

Table 5. Landscape Plant Water Requirements Calculator Coefficients		
Plant Coefficients		**Example 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%

RESULTS AND DISCUSSION

Results from the Year 2010 evaluations are summarized in Table 8 which shows the total irrigation volumes for each controller and station (zone). In Tables 9, 10 and 11, irrigation volumes are listed per season. Table 12 shows total irrigation volume over the entire study year in inches and as a percentage of ETo and ETc.

When looking at ***total irrigation amounts*** over the entire evaluation period:

- One (1) controller had five stations that were within +/- 20% of the recommendations of the TexasET Network
- One (1) controller had four stations within +/- 20% of the recommendations of the TexasET Network
- One (1) controller did not produce any stations within +/- 20% of the recommendations of the TexasET Network
- One (1) controller had a station that irrigated in excess of ETo.

Controller performance during the ***Spring evaluation period*** (March 29-May 30, 62 days) was generally poor.

- Two (2) controllers produced irrigation volumes in excess of ETc
- One (1) controller had irrigation volumes in excess of ETo.
- In total, 54% of the stations had excessive runtimes for the period, even though 4.27 inches of rainfall fell, eliminating the need for irrigation for most stations for four of the nine weeks.

Performance during the ***Summer evaluation period*** (May 31-August 30, 92 days) was fair.

- One (1) controller had 5 stations within +/- 20% the irrigation recommendations of TexasET.
- Two (2) controllers produced irrigation runtimes in excess of ETc, including one which irrigated in excess of ETo.
- Over nine inches of rainfall fell during this time frame meaning no controllers should have irrigated in excess of ETc.

Controller performance during the ***Fall evaluation period*** (August 31-November 22, 84 days) was slightly improved.

- Four controllers produced station runtimes in excess of ETc, including one station in excess of ETo.
- One (1) controller had 4 stations within +/- 20% the irrigation recommendations of TexasET.
- For this time frame, 67% (32 out of 48) of the stations irrigation amounts were between

the recommendations of the TexasET Network and that of calculated ETc (excluding rainfall).

Irrigation Adequacy Analysis

The purpose of the irrigation adequacy analysis is to identify controllers which over or under irrigate landscapes. A major difficulty in performing water balances is effective rainfall, how much of rainfall is credited for use by the plant. Further complicating rainfall is the use and performance of rain shut off devices by smart controllers.

For this study we broadly define irrigation ***adequacy*** as the range between taking 80% credit for all rainfall and taking no credit for rainfall. These limits are defined as:

- Extreme Upper Limit = ETo x Kc
- Adequacy Upper Limit = ETo x Kc x Af
- Adequacy Lower Limit = ETo x Kc - Net (80%) Rainfall
- Extreme Lower = ETo x Kc - Total Rainfall

The adequacy upper limit is defined as the plant water requirement (Equation 1) without rainfall. Irrigation volumes greater than the upper limit are classified as ***excessive***. The adequacy lower limit is defined as the plant water requirements minus Net Rainfall. The IA SWAT Protocol defines net rainfall as 80% of rainfall. Irrigation volumes less than the adequacy lower limit were therefore classified as ***inadequate***.

For comparison purposes, extreme limits were also defined by taking credit for no rainfall and total rainfall. These limits are the maximum and minimum plant water requirement.

Table 13 defines the controllers irrigation adequacy per station over the study period. Tables 14-16 show the controllers irrigation ***adequacy*** for the three seasonal periods. Details of these tables are graphed in Appendix C.

Rainfall was fairly consistent throughout the study. Since rainfall occurred, no station should have irrigated greater than the adequacy upper limit, however, five (5) stations did. Inadequacy was more common with onsite sensor based controllers, whereas excessive irrigating appeared more common among ET controllers.

- In Station 1, two (2) controllers irrigated in excess of the adequacy upper limit (despite the adequacy upper limit being was equal to maximum plant requirement).
- Stations 3 and 4 show the most inadequacy among the controllers.
- Five controllers did not meet the lower adequacy limit for the landscape, with two (2) controllers irrigating inadequately across half the stations.

Table 8. Total irrigation volumes over the entire testing period: Mar 29 - Nov 22, 2010. Also shown are the total ETo and Rainfall recorded during the evaluation period. Yellow denotes values within +/- 20% of TexasET Recommendation

	Station 1	**Station 2**	**Station 3**	**Station 4**	**Station 5**	**Station 6**
Plant Type	Flowers	Turf	Turf	Groundcover	Small Shrubs	Large Shrubs
A	26.93	20.83	14.37	12.48	13.13	9.17
B	35.48	19.61	14.43	10.31	10.92	0
C	16.59	18.37	14.88	5.6	8.97	5.8
D	16.96	7.87	6.26	3.84	5.31	2.9
E	14.07	7.22	4.82	4.07	4.91	1.66
F	20.93	12.69	9.82	6.3	3.58	3
G	27.4	15.8	8.58	5.32	8.04	0
H	46.1	16.29	11.78	7.34	12.47	5.04
TexasET Recommendation	23.61	13.47	9.67	6.33	9.40	3.64
ETc (ETo x Kc)[1]	33.22	24.92	24.92	20.77	20.77	12.46
ETo[2]	41.53					
Rainfall	17.98					

[1] Rainfall is not included in calculation

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

Table 9. Spring irrigation volumes, Mar 29 - May 30, 2010 (62 Days). Yellow denotes values within +/- 20% of TexasET Recommendation

Controller ID	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
A	6.30	6.55	4.10	3.03	3.68	2.50
B	10.0	5.46	4.04	2.89	3.19	0
C	5.93	6.52	5.22	1.72	2.72	1.73
D	4.87	2.25	1.79	0.75	1.52	0.72
E	4.96	2.76	2.20	1.53	1.87	1.12
F	6.61	3.91	3.03	1.80	0.72	0.70
G	7.82	4.15	1.99	1.29	1.47	0
H	12.32	4.64	3.28	2.15	3.62	1.45
Total ETo[1]	11.10					
Total Rainfall[2]	4.27					
TexasET Recommendation	6.14	3.30	2.23	1.31	1.93	0.75
Total ETc[3]	8.88	6.66	6.66	5.55	5.55	3.33

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

[2] Total Rainfall collected from TexasET Network Weather Station "TAMU Golf Course"

[3] Rainfall and Adjustment Factor not included in this calculation

Table 10. Summer irrigation volumes, May 31 - Aug 30, 2010 (92 Days). Yellow denotes values within +/- 20% of TexasET Recommendation

Controller ID	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
A	13.14	10.11	7.28	6.33	6.30	4.17
B	15.90	8.96	6.64	4.74	4.55	0
C	3.35	3.15	2.57	1.15	1.83	1.17
D	4.17	1.70	1.35	0.94	1.15	0.73
E	2.45	1.72	0.76	0.83	1.20	0
F	3.80	2.08	1.66	1.18	0.27	0.13
G	10.66	6.59	3.44	2.32	4.19	0
H	20.87	6.82	4.97	3.01	5.20	2.13
Total ETo[1]	19.18					
Total Rainfall[2]	9.12					
TexasET Recommendation	11.57	6.63	4.78	3.17	4.64	1.78
Total ETc[3]	15.34	11.51	11.51	9.59	9.59	5.75

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

[2] Total Rainfall collected from TexasET Network Weather Station “TAMU Golf Course”

[3] Rainfall and Adjustment Factor not included in this calculation

Table 11. Fall irrigation volumes, Aug 31 - Nov 22, 2010 (84 Days). Yellow denotes values within +/- 20% of TexasET Recommendation

Controller ID	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6
A	7.49	4.17	2.99	3.12	3.15	2.50
B	9.58	5.19	3.75	2.68	3.18	0
C	7.31	8.70	7.09	2.73	4.42	2.90
D	7.92	3.92	3.12	2.15	2.64	1.45
E	6.66	2.74	1.86	1.71	1.84	0.54
F	10.52	6.70	5.13	3.32	2.59	2.17
G	8.92	5.06	3.15	1.71	2.38	0
H	12.91	4.83	3.53	2.18	3.65	1.46
Total ETo[1]	11.25					
Total Rainfall[2]	4.59					
TexasET Recommendation	5.90	3.54	2.66	1.85	2.83	1.11
Total ETc[3]	9.00	6.75	6.75	5.63	5.63	3.38

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

[2] Total Rainfall collected from TexasET Network Weather Station "TAMU Golf Course"

[3] Rainfall and Adjustment Factor not included in this calculation

Table 12. Comparison of total volumes (inches) of each controller to plant water requirements and ETo over the entire evaluation period.

Total	A	B	C	D	E	F	G	H
Irrigation Applied, in	96.91	90.75	70.21	43.14	36.75	56.32	65.14	99.02
% ETc	71%	66%	51%	31%	27%	41%	48%	72%
% ETo	39%	36%	28%	17%	15%	23%	26%	40%
TexasET Rec.	66.12							
ETc (ETo x Kc)[1]	137.06							
ETo	249.18							
Rainfall	17.98							

[1] effective rainfall not subtracted

Table 13. Irrigation adequacy over the entire 2010 evaluation period.

Controller	Station 1	Station 2	Station 3	Station 4	Station 5	Station6
A	Adequate	Excessive	Adequate	Excessive	Adequate	Excessive
B	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate
C	Inadequate	Adequate	Adequate	Inadequate	Adequate	Adequate
D	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
E	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
F	Adequate	Adequate	Inadequate	Inadequate	Inadequate	Adequate
G	Adequate	Adequate	Inadequate	Inadequate	Adequate	Adequate
H	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate

Table 14. Irrigation adequacy during the 2010 Spring testing period.

Controller	Station 1	Station 2	Station 3	Station 4	Station 5	Station6
A	Adequate	Excessive	Excessive	Excessive	Adequate	Excessive
B	Excessive	Excessive	Excessive	Excessive	Adequate	Adequate
C	Adequate	Excessive	Excessive	Inadequate	Adequate	Excessive
D	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
E	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
F	Adequate	Adequate	Inadequate	Inadequate	Inadequate	Adequate
G	Adequate	Adequate	Inadequate	Inadequate	Inadequate	Adequate
H	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate

Table 15. Irrigation adequacy during the 2010 Summer evaluation period.

Controller	Station 1	Station 2	Station 3	Station 4	Station 5	Station6
A	Adequate	Excessive	Excessive	Excessive	Adequate	Excessive
B	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate
C	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
D	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
E	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
F	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
G	Adequate	Adequate	Inadequate	Adequate	Adequate	Adequate
H	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate

Table 16. Irrigation adequacy during the 2010 Fall evaluation period.

Controller	Station 1	Station 2	Station 3	Station 4	Station 5	Station6
A	Adequate	Adequate	Inadequate	Excessive	Adequate	Excessive
B	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate
C	Adequate	Excessive	Excessive	Adequate	Excessive	Excessive
D	Adequate	Adequate	Adequate	Adequate	Adequate	Adequate
E	Adequate	Inadequate	Inadequate	Inadequate	Inadequate	Adequate
F	Excessive	Excessive	Excessive	Excessive	Adequate	Excessive
G	Adequate	Adequate	Adequate	Inadequate	Adequate	Adequate
H	Excessive	Adequate	Adequate	Adequate	Adequate	Adequate

CONCLUSIONS AND FUTURE PLANS

Over the past five 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 problem. In the past four years of bench tesiting, we have seen some reduction in excessive irrigation charactaristic of a few controllers.

Our emphais continues to be an "end-user" evaluation, how controllers preform as installed in the field. The "end-user" is defined as the landscape or irrigation contractor (such as a licensed irrigator in Texas) who installs and programs the controller.

Although the general performance of the controllers has gradually increased over the last four years, we continue to oberserve controllers irrigating in excess of ETc. Since ETc is defined as the ETo x Kc, this should be the greatest amount of water a plant should need over any time frame if no rainfall occurs. However three controllers consistently irrigated in excess of ETc even though over 17 inches of rainfall fell during this typical irrigation season.

The factors that could cause this over irrigation are improper ETo calculation/aquisition and insufficient accounting for rainfall. Appendix B contains ET values recorded off controllers along with corresponding daily ET from the TexasET Network. Of the eight (8) smart controllers in the study, three (3) were equiped with "tipping-bucket" type rain gauges which actually measure rainfall, while the other five (5) controllers were equiped with rainfall shutoff sensors as required by Texas law. Rainfall shutoff sensors only detected the presense of rainfall and interrup the irrigation event. Of the three controllers which used "tipping-bucket" gauges, two were consitently among the top three (3) performing smart controllers, especially during the summer period when the greatest amount of rainfall occured.

The controllers' ability to adequately meet the plants water requirement is used to define performance. Of the eight (8) controllers tested, none of the controllers were consitently able to adequately meet the plant water requirements throught the entire season. Our evaluation results over the last three (3) years have consistently shown that the majority of controllers over-irrigate (i.e., apply more water than is resonaby needed). Out of a total of 144 stations, 40 stations (over the 3 individual seasons) showed inadequate irrigations compared to only 30 stations showing excessive irrigation amounts meaning only 74 stations irrigated adequately.

Generally, controllers with on-site sensors, performed better and more often irrigated closer to the recommendations of the TexasET Network than those controllers which have ET sent to the controller. However, it was observed that irrigation inadequacy was more common among on site senor controllers where as irrigation excess occurred more often among the ET subscription based controllers.

Current plans are to continue evaluation of controllers utlizing their existing programming into the 2011 year to replicate or verify 2010 year results. While water savings shows promise through the use of some smart irrigation controllers, excessive irrigation is still occuring under some landscape scenerios. Continued evaluation and work with the manufacturers is needed to fine tune these controllers even more to achieve as much water savings as possible.

Appendix A

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

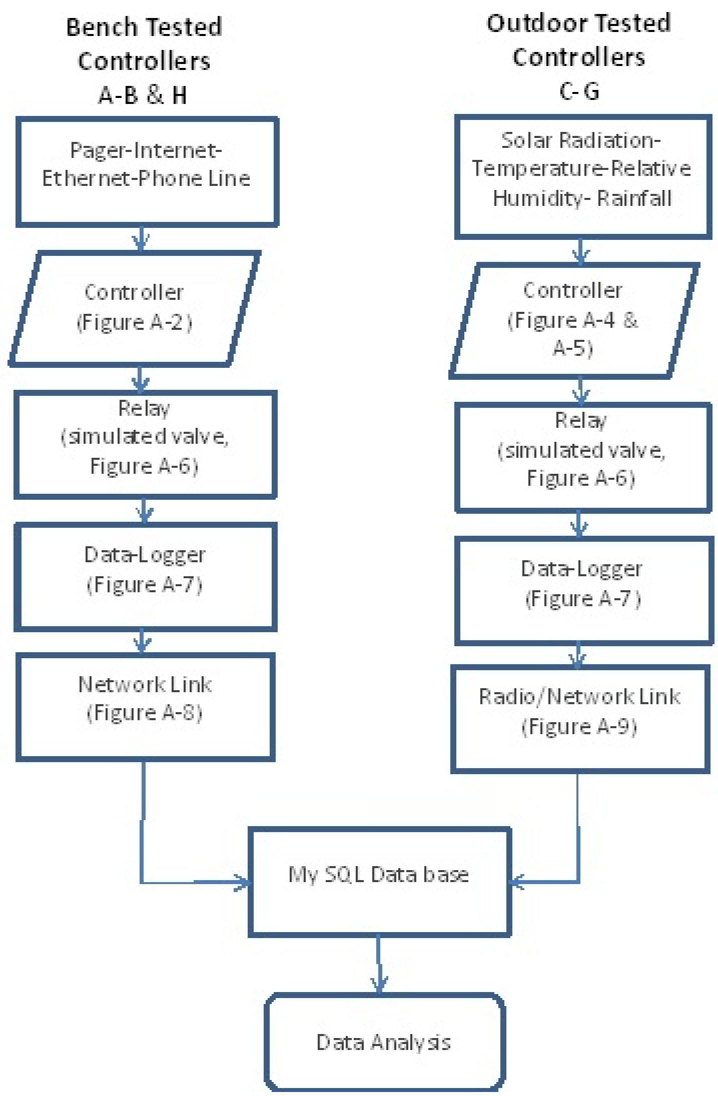


Figure A-2. Bench Tested Controllers

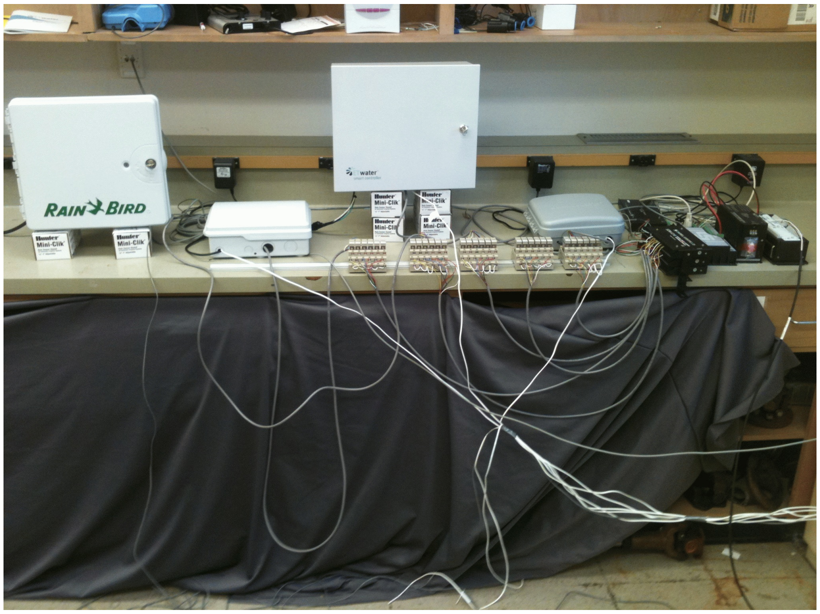


Figure A-3. Indoor Tested Controllers Rain Sensors

Figure A-4. Outdoor Tested Controllers

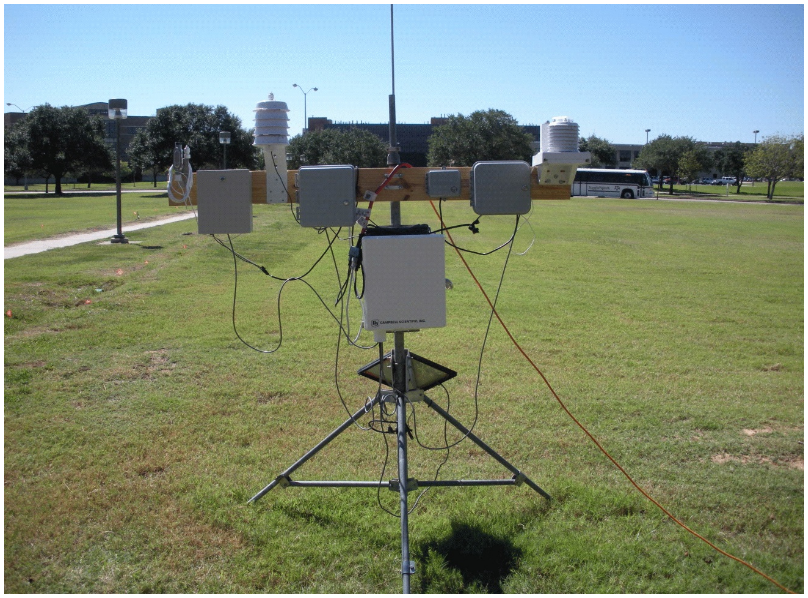


Figure A-5. Outdoor Tested Controller (cont)

Figure A-6. Relays

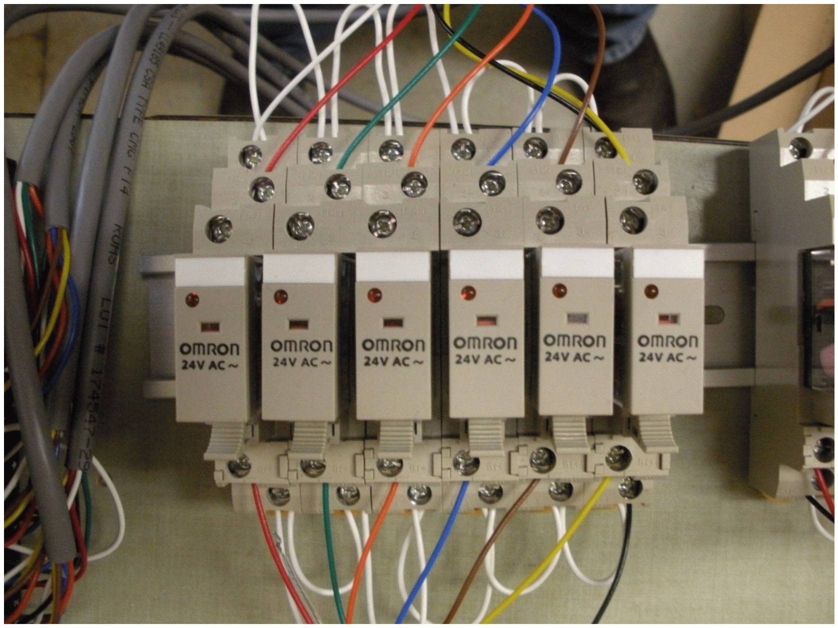


Figure A-7. Datalogger

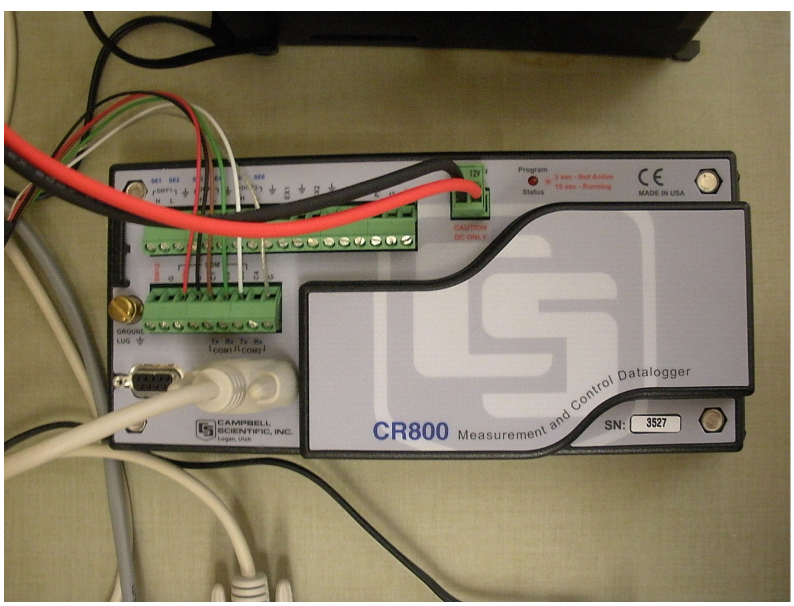


Figure A-8. Network Link

Figure A-9. Radio/Network Link

Appendix B

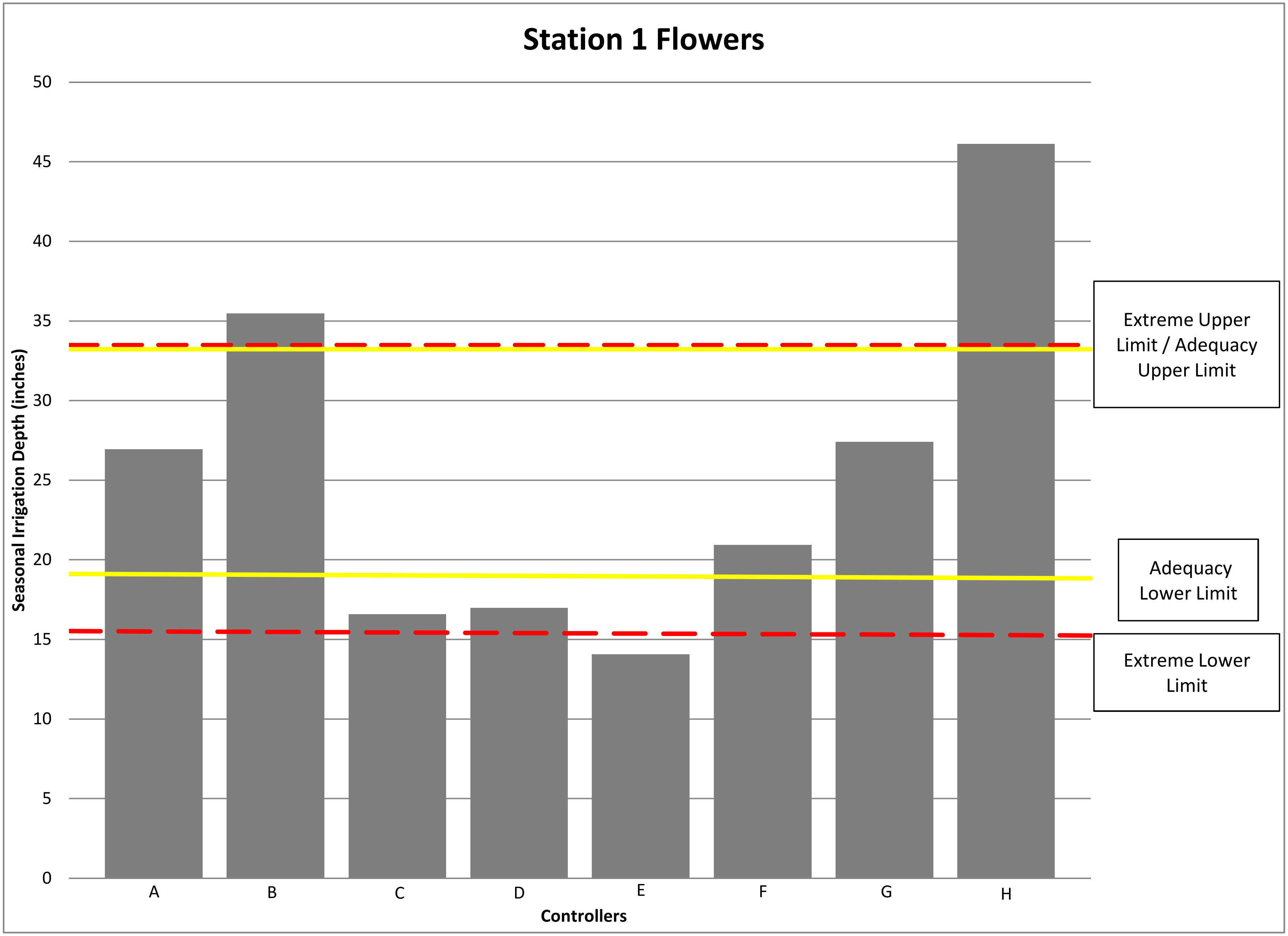
ET Values that were recorded off controllers							
Controller	A	B	E	G	H		
Date	ET Water[1]	Rainbird ET Manager	Hunter ET	Rainbird ESP-SMT	Toro[2]	Texas ET ETo	Texas ET Rainfall
9/1/10			0.08	0.23	0.2	0.21	0
9/2/10	1.52	0.16	0.08			0.15	0.01
9/6/10	1.31	0.2	0.11	0.23		0.14	0.12
9/7/10	1.32	0.08	0.02	0.2		0.04	2.3
9/8/10	1.19	0.14	0.03	0.13	.07\1.28	0.12	0.48
9/9/10	1.12	0.17	0.04	0.16	.13\1.20	0.15	0.13
9/10/10	1.1	0.18				0.19	0
9/12/10				0.22		0.16	0
9/13/10	1.08	0.19	0.1	0.23	.22\1.18	0.18	0
9/14/10	1.07	0.19		0.23		0.19	0
9/15/10	1.16	0.23	0.12	0.23	.22\1.33	0.2	0
9/16/10	1.2	0.21	0.12	0.21	.20\1.47	0.16	0
9/17/10	1.24	0.2	0.16	0.25	0.22	0.16	0
9/20/10	1.23	0.08	0.07	0.19	.20\1.49	0.14	0
9/21/10	1.21	0.13	0.07	0.19	0.2	0.13	0
9/22/10		0.12	0.08	0.17	.29\1.28	0.17	0
9/23/10	1.17	0.22	0.07	0.19	.19\1.27	0.16	0
9/24/10	1.13	0.17	0.08	0.18	0.18	0.15	0.32
9/27/10	1.1	0.17	0.12	0.19	.18\1.17	0.15	0
9/28/10	1.09	0.25	0.15	0.18	.18\1.15	0.13	0
9/29/10	1.12	0.21	0.15	0.2	.19\1.31	0.14	0
9/30/10	1.13	0.27	0.16	0.21	.20\1.32	0.16	0
10/1/10		0.22	0.15	0.22	.19\1.33	0.17	0
10/4/10	1.1	0.3	0.15	0.22	.17\1.31	0.14	0
10/5/10	1.09	0.29	0.15	0.16	.18\1.30	0.13	0
10/6/10	1.07	0.31	0.15	0.19	.18\1.28	0.11	0
10/7/10	1.05	0.26	0.16	0.2	.17\1.28	0.11	0
10/8/10	1.04	0.29	0.16	0.2	.17\1.25	0.14	0
10/11/10	1.13	0.16	0.1	0.17	.18\1.24	0.15	0
10/12/10	1.14	0.17	0.11	0.17	.17\1.23	0.14	0
10/13/10	1.14	0.33	0.14	0.18	.18\1.22	0.14	0
10/14/10	1.14	0.27	0.13	0.19	.18\1.23	0.13	0
10/15/10	1.14	0.31	0.11	0.16	.17\1.19	0.1	0
10/18/10	1.05	0.13	0.09	0.16	.12\1.12	0.13	0
10/19/10	1.03	0.17	0.06	0.16	.11\1.05	0.12	0
10/20/10	1.01	0.19	0.1	0.16	.11\.92	0.14	0
10/21/10	1.01	0.24	0.09	0.17	.15\.97	0.14	0
10/22/10	1.01	0.14	0.08	0.15	0.13	0.15	0
10/25/10	0.92	0.16	0.05	0.15	.14\.84	0.17	0

10/26/10	0.92	0.18	0.08	0.14	.11\.84	0.16	0
10/27/10			0.1	0.17	.14\.86	0.11	0
10/28/10	0.91	0.17		0.18	.13\.86	0.2	0
10/29/10	0.89		0.13	0.12	0.15	0.11	0
11/1/10	0.92	0.16	0.12	0.15	.15\.94	0.1	0
11/2/10	0.92		0.05	0.14	.13\.96	0.09	0.21
11/3/10	0.88		0.01	0.1	.13\.95	0.05	0.01
11/4/10	0.78	0.04	0.04	0.08	.02\.79	0.12	0
11/5/10	0.75		0.12	0.1	.02\.79	0.1	0
11/8/10	0.71	0.13	0.12	0.12	.12\.65	0.13	0
11/9/10	0.65	0.12	0.07	0.12	.12\.68	0.12	0
11/10/10	0.63	0.08	0.06	0.12	.09\.68	0.1	0
11/11/10	0.74	0.07	0.04	0.14	.09\.78	0.09	0
11/12/10	0.75	0.07	0.04	0.12	.06\.72	0.11	0.26
11/15/10	0.69	0.03	0	0.07	.10\.66	0.03	0.13
11/16/10	0.64	0.07	0.02	0.08	.06\.59	0.1	0
11/18/10	0.6	0.14	0.08	0.12	.10\.62	0.08	0
11/19/10	0.58	0.09	0.08	0.1	.09\.64	0.08	0

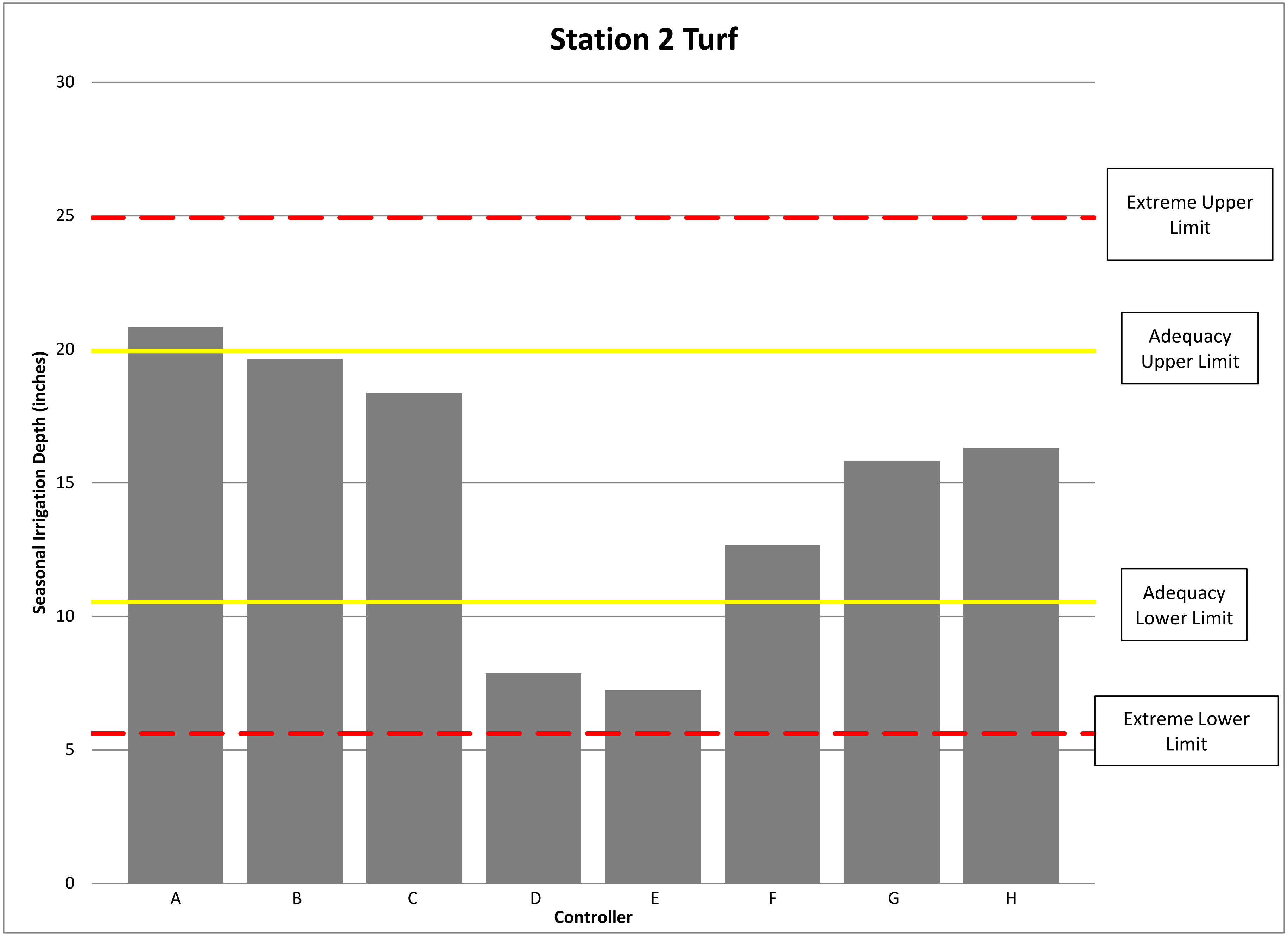
1 Controller Reported a 7 Day Total ET

2 Controller reported both daily and 7 day total ET

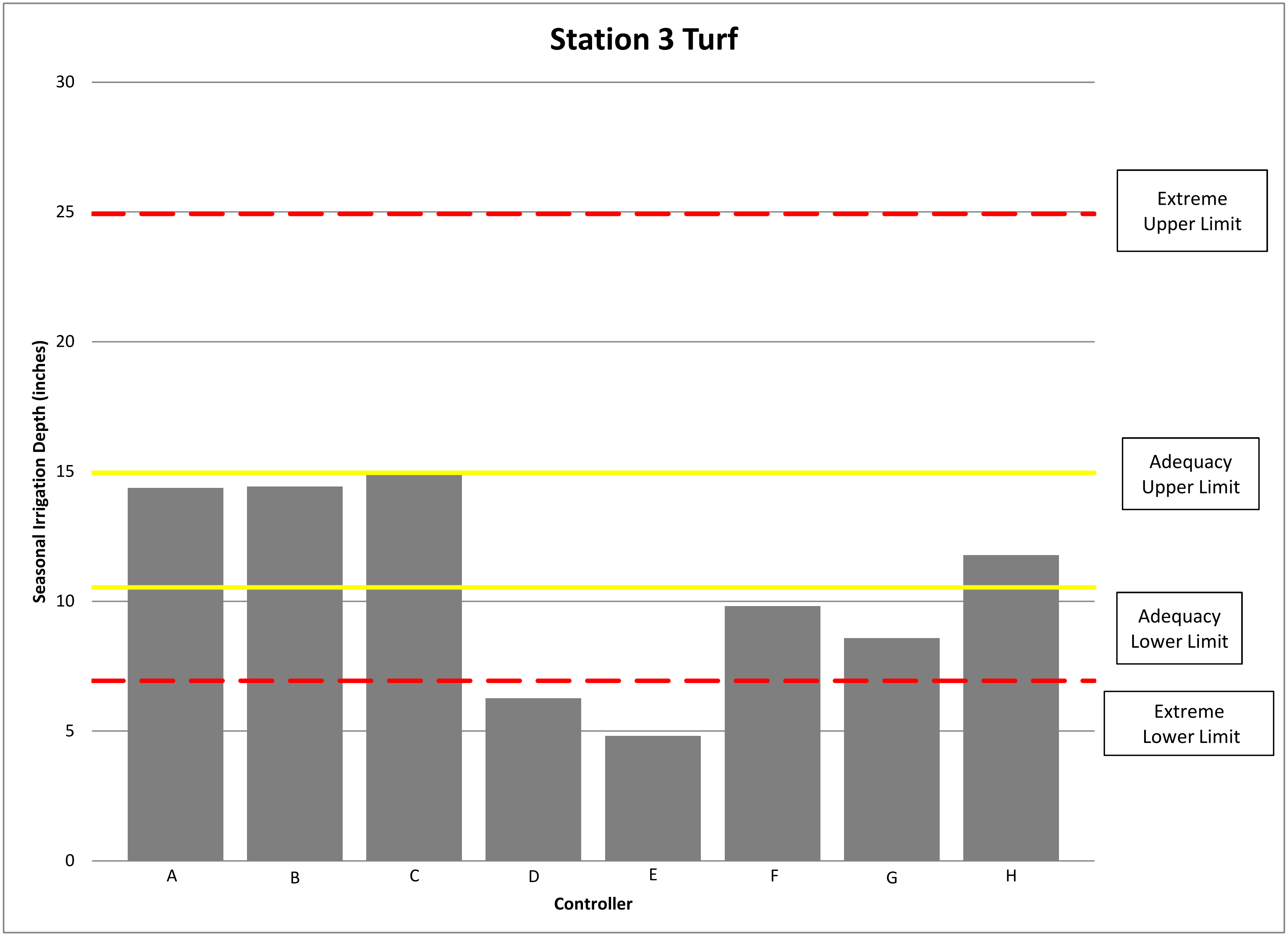
Appendix C

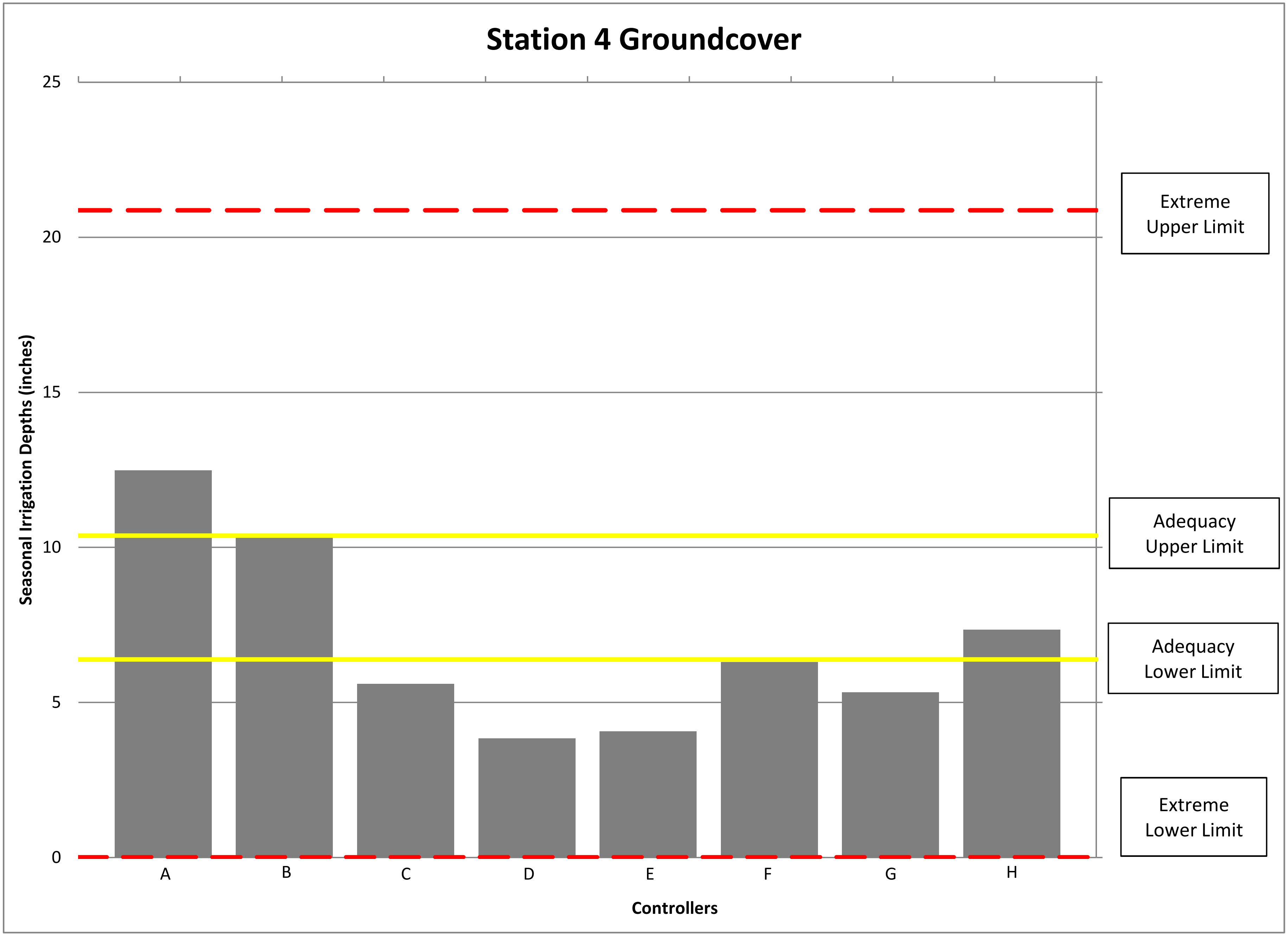


Station 1 Flowers
50
45
40
35
30
25
20
15
10
5
0
Seasonal Irrigation Depth (inches)
A
B
C
D
E
F
G
H
Controllers
Extreme Upper Limit / Adequacy Upper Limit
Adequacy Lower Limit
Extreme Lower Limit

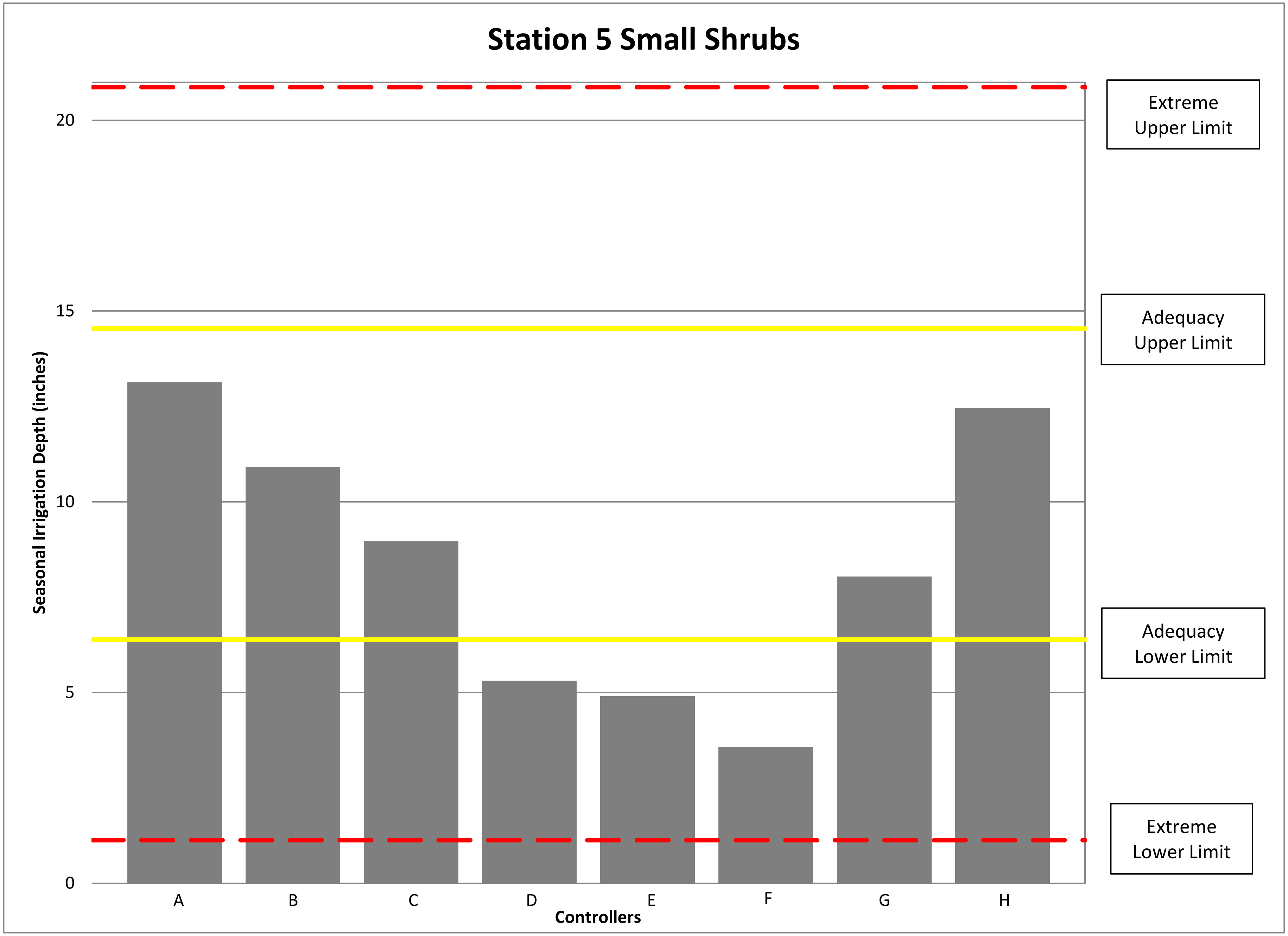


Station 2 Turf
Seasonal Irrigation Depth (inches)
30
25
20
15
10
5
0
A
B
C
D
E
F
G
H
Controller
Extreme Upper Limit
Adequacy Upper Limit
Adequacy Lower Limit
Extreme Lower Limit

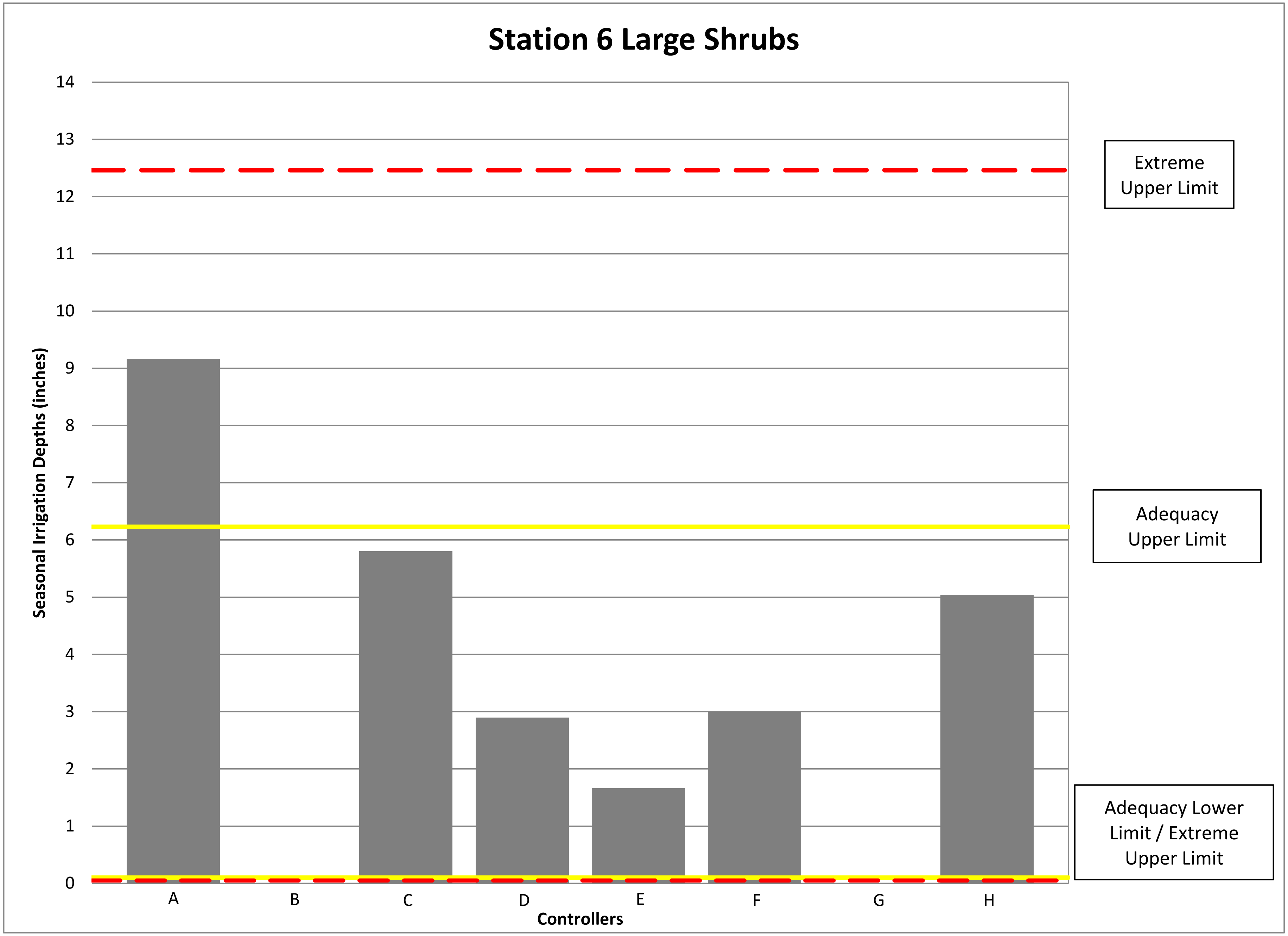

Station 3 Turf
30
25
20
15
10
5
0
Seasonal Irrigation Depth (inches)
A
B
C
D
E
F
G
H
Controller
Extreme Upper Limit
Adequacy Upper Limit
Adequacy Lower Limit
Extreme Lower Limit



Station 4 Groundcover
25
20
15
10
5
0
Seasonal Irrigation Depths (inches)
A
B
C
D
E
F
G
H
Controllers
Extreme Upper Limit
Adequacy Upper Limit
Adequacy Lower Limit
Extreme Lower Limit



Station 5 Small Shrubs
Seasonal Irrigation Depth (inches)
0
5
10
15
20
A
B
C
D
E
F
G
H
Controllers
Extreme Upper Limit
Adequacy Upper Limit
Adequacy Lower Limit
Extreme Lower Limit


Station 6 Large Shrubs
Seasonal Irrigation Depths (inches)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
A
B
C
D
E
F
G
H
Controllers
Extreme Upper Limit
Adequacy Upper Limit
Adequacy Lower Limit / Extreme Upper Limit

Texas Water Resources Institute
make every drop count

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