Full Season Comparison of Weather Based Smart Controllers

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Abstract

Several weather based smart controllers at Berthoud, Colorado were programmed to manage six virtual landscape zones over the 2015-2016 seasons. These virtual landscape zones covered a wide variety of soil types, plant materials, and irrigation methods but were the same six landscapes given each controller. The zone valve control outputs on each controller were connected to switches/relays monitored by a data logger which recorded the minutes of runtime for every irrigation cycle of all six zones on each controller. Controller performance was obtained by importing these irrigation events into a daily soil moisture depletion/balance spreadsheet using the dual Kc method for calculating plant water use.

The dual coefficient method partitions ET into evaporation from wetted surfaces and transpiration through vegetation. The increased evaporation following rain or irrigation events and the reduced transpiration resulting from soil moisture depletions were calculated day-by-day for the both the controller determined and the 'preferred' watering for each zone. Both were calculated using the same spreadsheet.

Controllers able to water deeply but less frequently to meet plant needs and/or that directly account for onsite rainfall compared closer to the 'preferred' watering needs than those which did not.

Keywords: Irrigation, Controller, Landscape, Smart, Scheduling, Water management

Weather Based Smart Controllers and Virtual Landscape Zones

The irrigation controllers utilized in this comparison are listed below in Table 1.

Table 1. Irrigation controllers

Manufacturer	Model	Weather Source
Rain Bird	ESP-SMTe	Onsite sensors for air temperature and tipping bucket rain
Irrisoft Rain Bird	Weather Reach Controller Link ESP-Me	Data from onsite weather station via Internet
Toro	Evolution	EVO-WS sensors for air temperature, sunlight, and rain delay
Weathermatic	Smart Line SL1600	SLW5 sensors for air temperature and rain delay
Irritrol	Rain Dial-R	Climate Logic sensors for air temperature, sunlight, and rain delay
HydroPoint	WeatherTRAK LC Central	ET Everywhere service - cellular

All six virtual landscapes used in this comparison are included below in Table 2. Their parameters vary significantly. However, to avoid becoming overly complex and redundant, only the results for Zone 1 are presented.

Table 2. Virtual landscape zones

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Plants	Cool season turf	Fescue	Ground cover	Trees	Woody shrubs / non-desert	Warm season turf
Veg factor, Kv	0.92	0.92	1.03	1.22	0.84	0.88
Density, Kd	1	1	0.85	0.98	0.9	1
Effective Root depth	10-inch	8-inch	9-inch	20-inch	15-inch	5-inch
Typical plant height	3.5-inch	3.5-inch	10-inch	177-inch	30-inch	3.5-inch
Managed stress	High	Ave	Low	Low	Low	Ave
Managed stress, Ksm	0.7	0.8	0.8	0.8	0.8	0.7
MAD	0.8	0.72	0.76	0.87	0.87	0.83
Fraction of organic mulch	n/a	n/a	0.25	0.75	0.75	n/a
Soil type	Silty clay	Loam	Loamy sand	Sandy loam	Silty clay loam	Clay
Slope	4%	8%	6%	2%	10%	12%
Exposure	Full sun	77% shaded	Full sun	50% shaded	Full sun	Full sun
Micro-climate factor, Kmc	1	0.65	1	0.77	1	1
Irrigation method	Spray sprinklers	Spray sprinklers	Spray sprinklers	Rotor sprinklers	Surface drip grid	Rotor sprinklers
Application rate	1.10-iph	1.35-iph	1.60-iph	0.60-iph	0.24-iph	0.42-iph
Irrigation application efficiency	70%	65%	60%	75%	80%	70%
Irrigation interval	MAD	MAD	MAD	MAD	MAD	MAD

Two Season Results

The soil moisture depletion/balance spreadsheet utilized for this comparison began on January 1st 2015 through October 31st 2016. However, the irrigation season was restricted to May 1st through October 31st of each year. Consequently, the following summary charts for Zone 1 cover the irrigation season only.

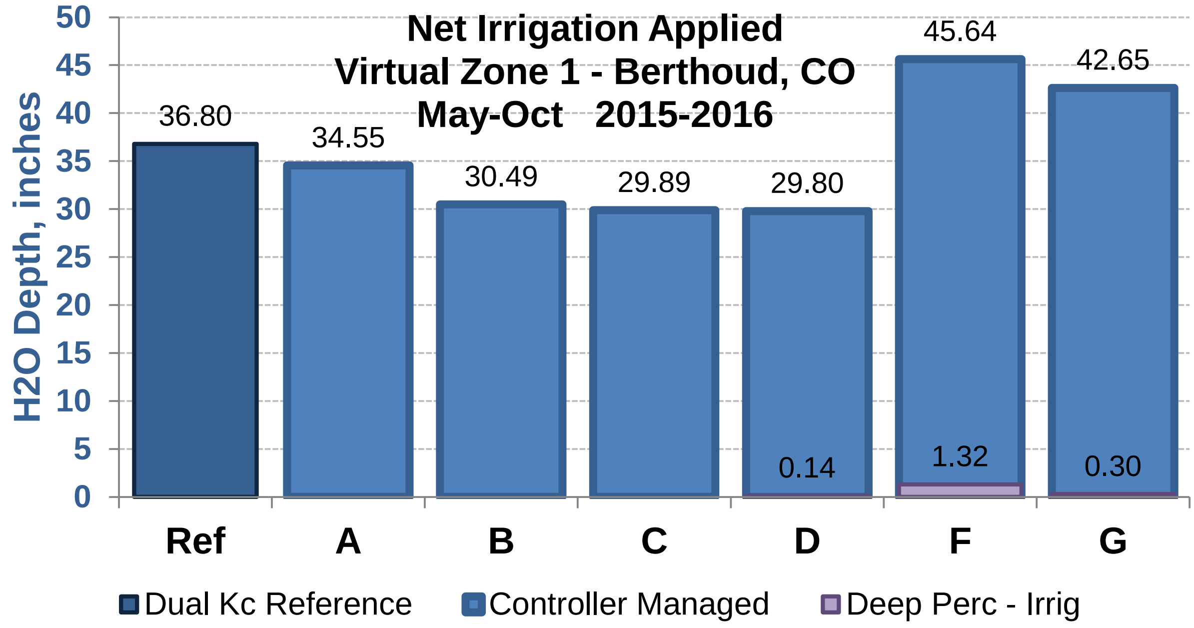

Figure 1. Net irrigation applied to Zone 1 during May-Oct of 2015 and 2016 seasons at Berthoud, Colorado. Depths are the sum of both seasons. Deep percolation losses from irrigation only occurred under controllers D, E, and F.

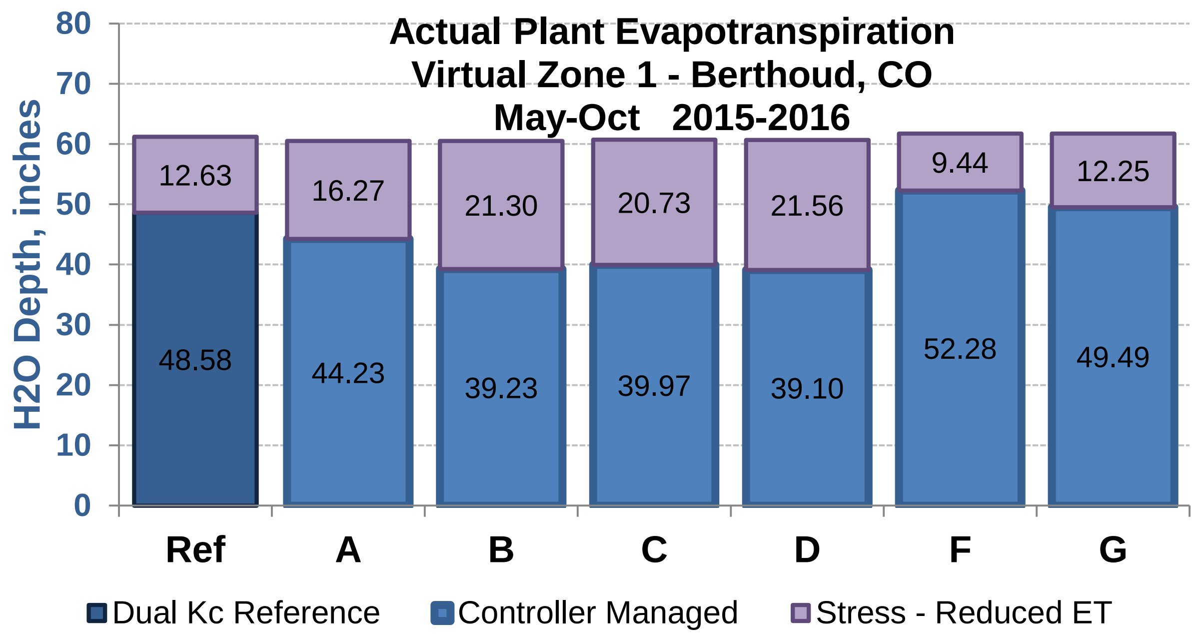

Figure 2. Plant evapotranspiration obtained from the dual Kc method for calculating plant water use Zone 1 during May-Oct of 2015 and 2016 seasons at Berthoud, Colorado. Depths are the sum of both seasons. Included in Figure 2 is the reduction in ET resulting from soil moisture depletions or water stress.

Daily Soil Moisture Depletions - 2015

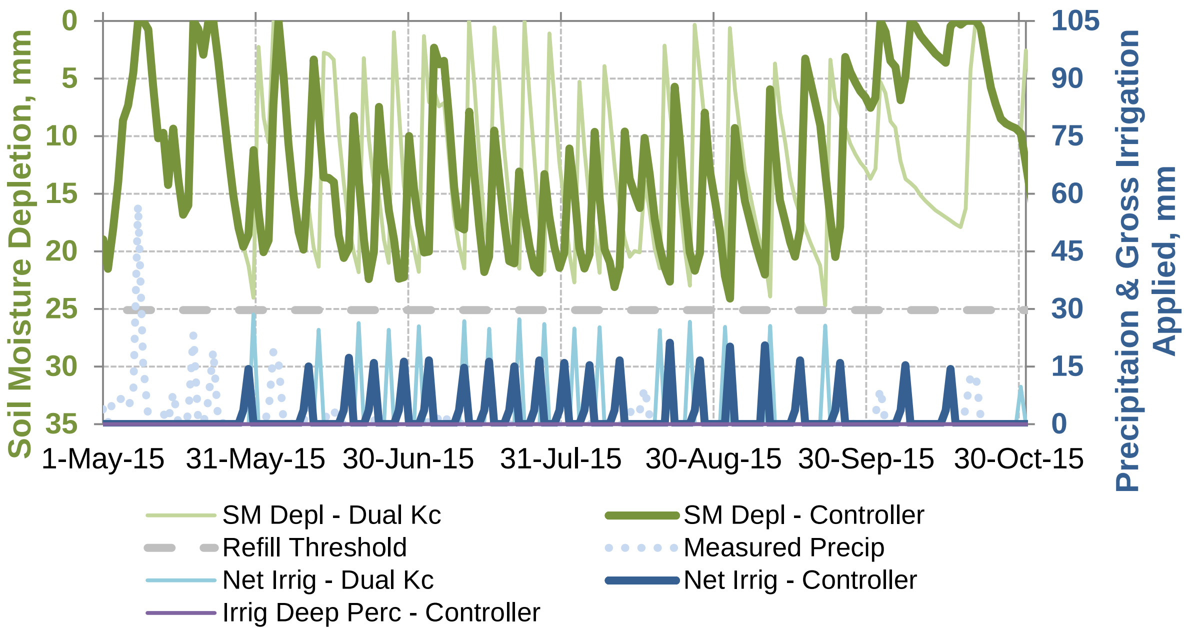

Figure 3. Daily soil moisture depletions for Controller A - Zone 1 during 2015 season at Berthoud, Colorado.

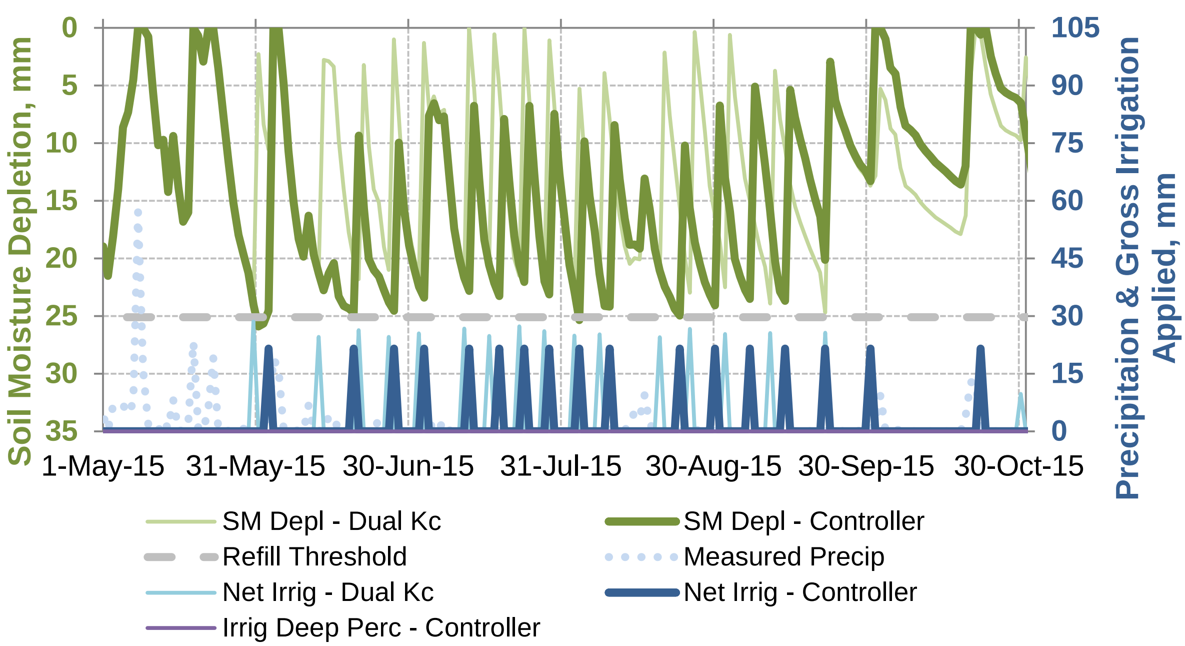

Figure 4. Daily soil moisture depletions for Controller B - Zone 1 during 2015 season at Berthoud, Colorado.

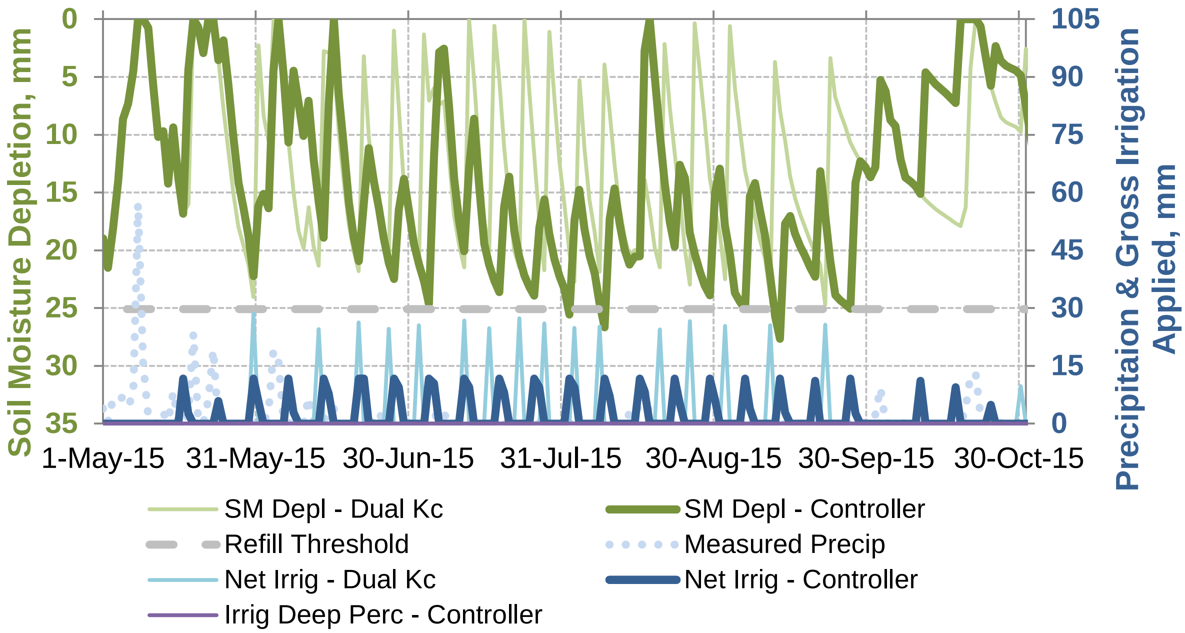

Figure 5. Daily soil moisture depletions for Controller C - Zone 1 during 2015 season at Berthoud, Colorado.

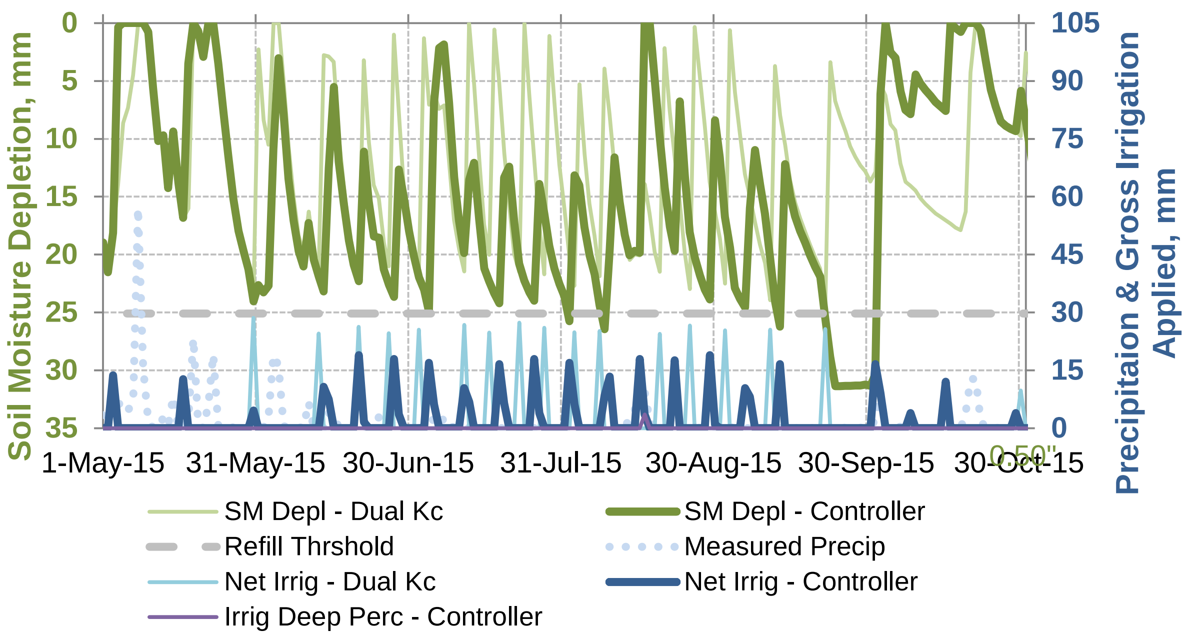

Figure 6. Daily soil moisture depletions for Controller D - Zone 1 during 2015 season at Berthoud, Colorado. The rain delay sensor precluded needed irrigation in late September.

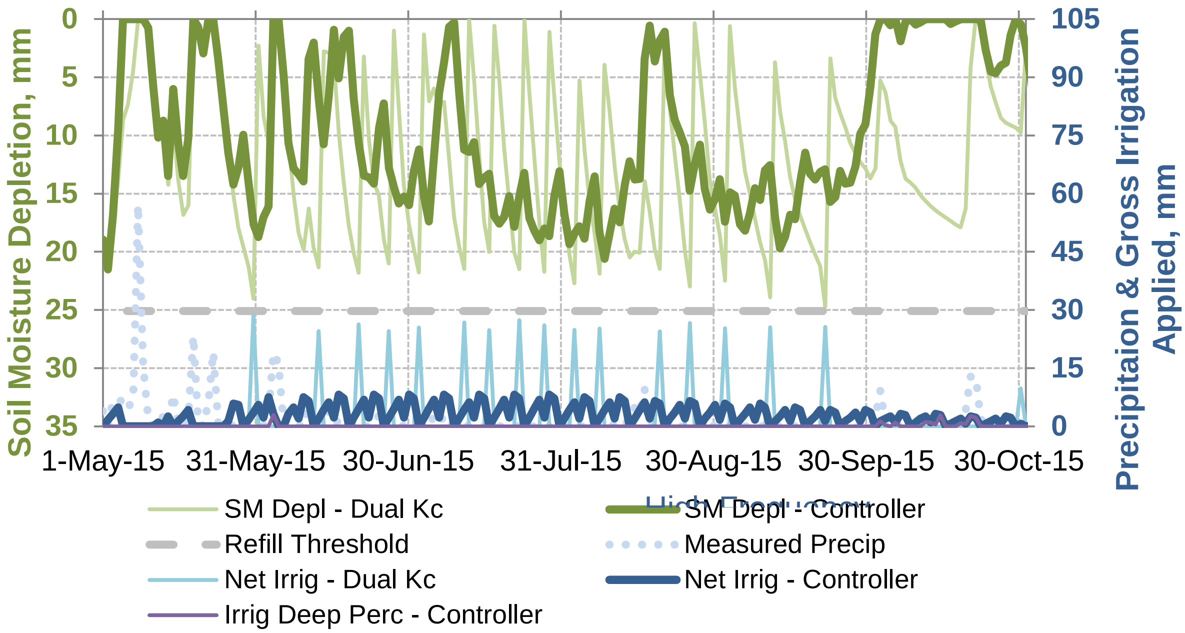

Figure 7. Daily soil moisture depletions for Controller F - Zone 1 during 2015 season at Berthoud, Colorado. This controller called for higher frequency of irrigation.

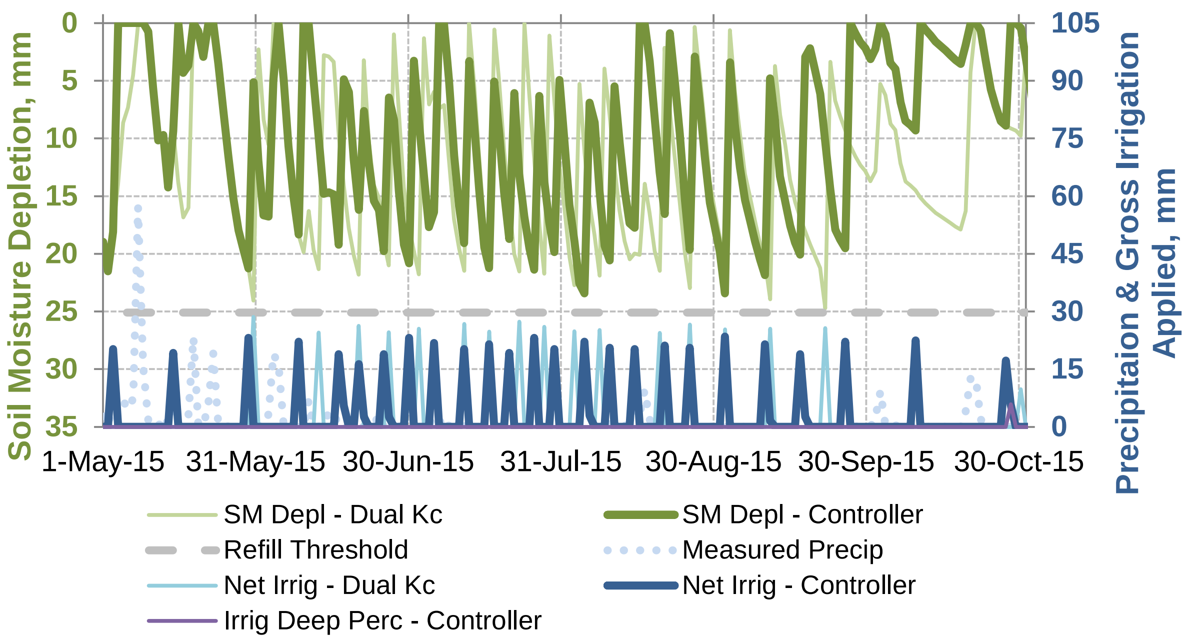

Figure 8. Daily soil moisture depletions for Controller G - Zone 1 during 2015 season at Berthoud, Colorado.

Daily Soil Moisture Depletions - 2016

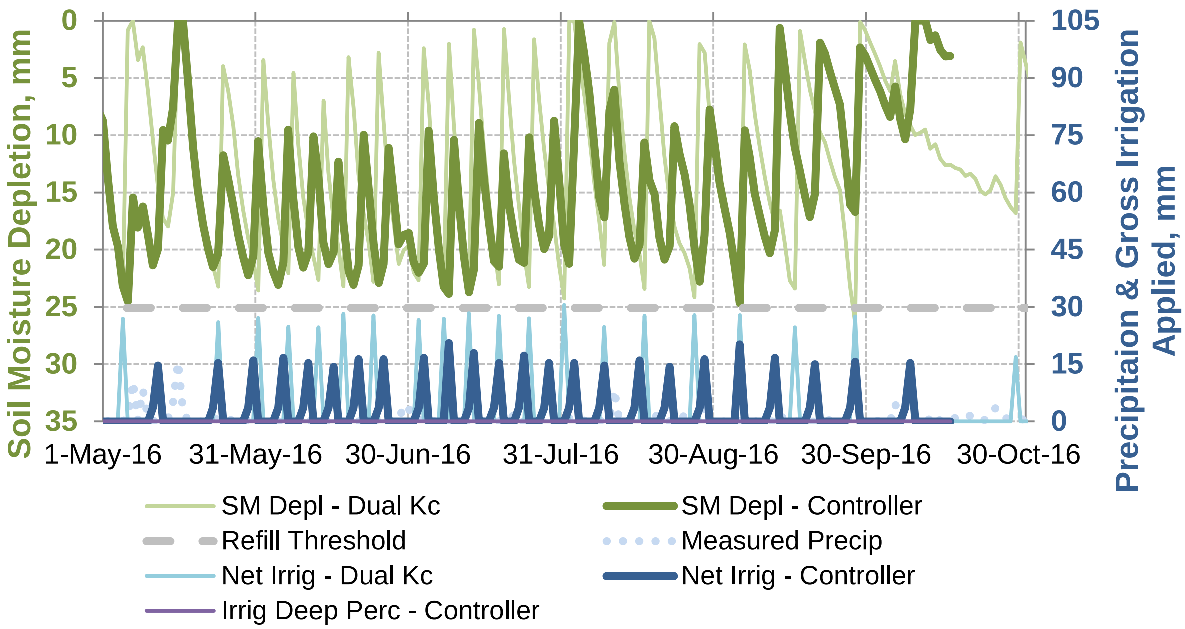

Figure 9. Daily soil moisture depletions for Controller A - Zone 1 during 2016 season at Berthoud, Colorado.

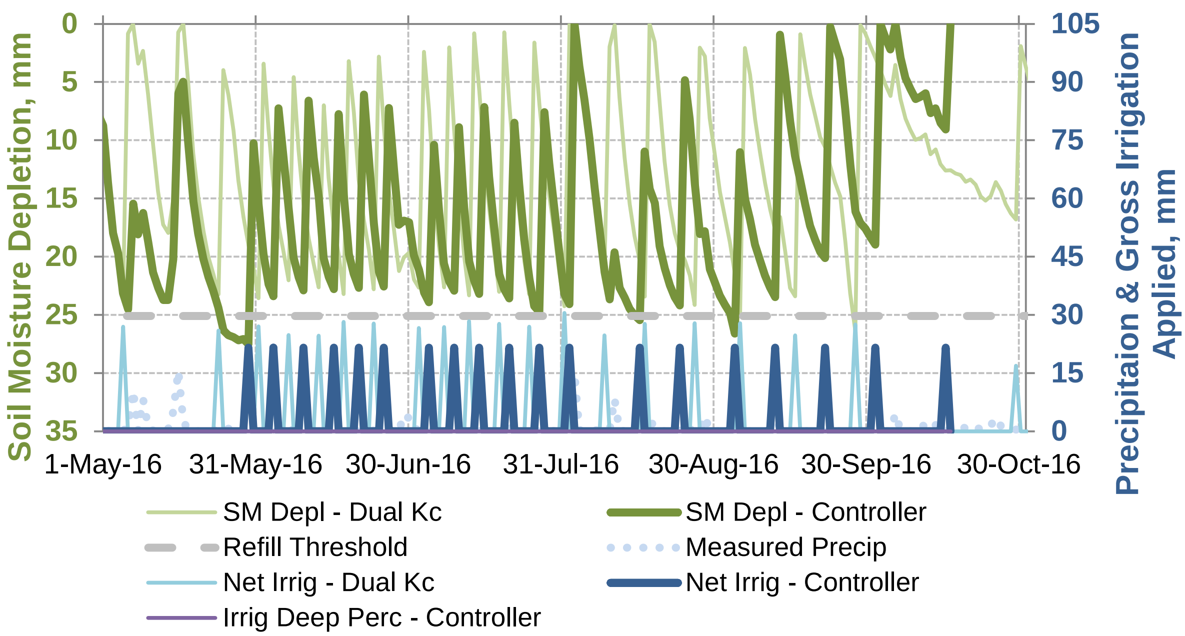

Figure 10. Daily soil moisture depletions for Controller B - Zone 1 during 2016 season at Berthoud, Colorado.

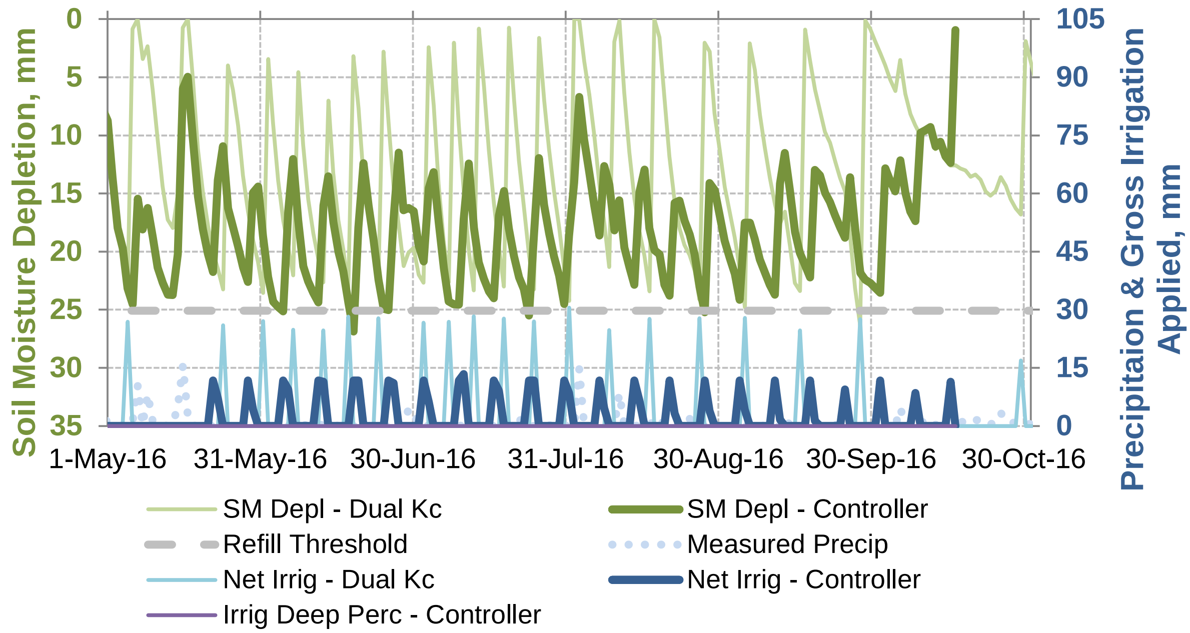

Figure 11. Daily soil moisture depletions for Controller C - Zone 1 during 2016 season at Berthoud, Colorado.

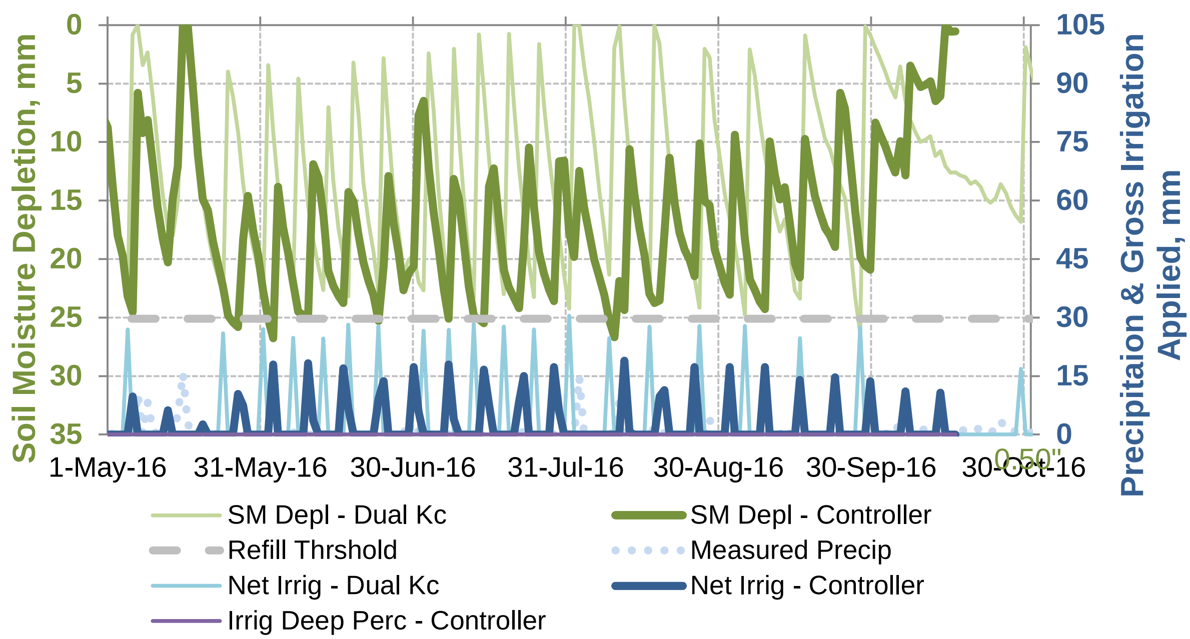

Figure 12. Daily soil moisture depletions for Controller D - Zone 1 during 2016 season at Berthoud, Colorado.

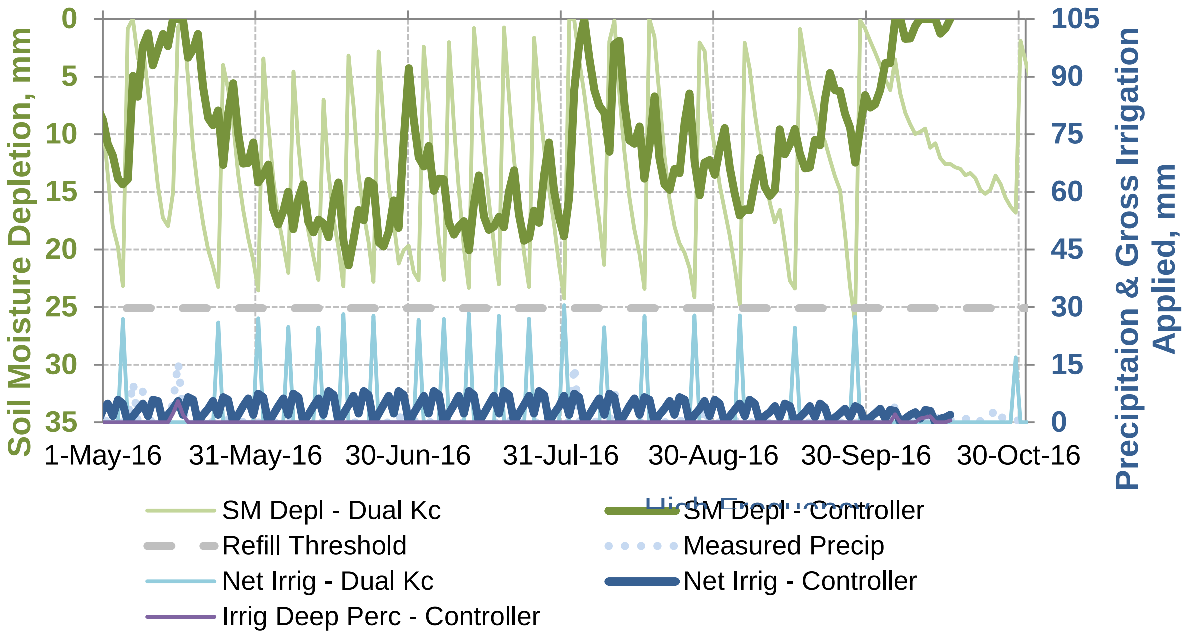

Figure 13. Daily soil moisture depletions for Controller F - Zone 1 during 2016 season at Berthoud, Colorado. This controller called for higher frequency of irrigation.

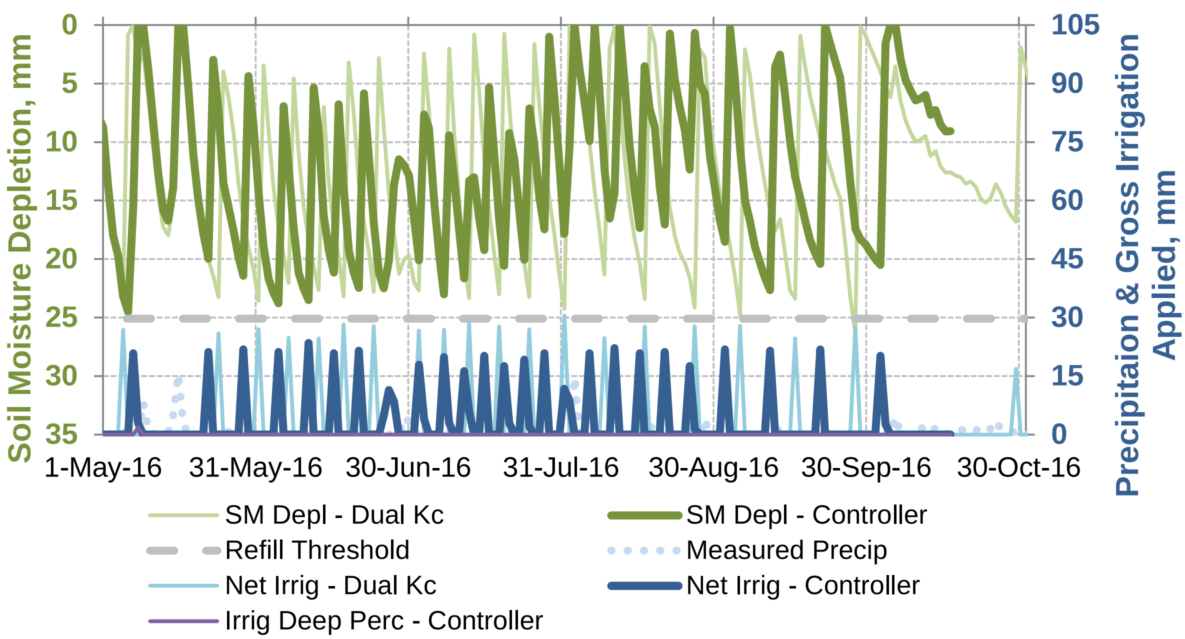

Figure 14. Daily soil moisture depletions for Controller G - Zone 1 during 2016 season at Berthoud, Colorado.

Reference ET

The ASCE standardized evapotranspiration equation (Allen, 2005) was utilized to provide reference evapotranspiration or ET_o. Weather data was obtained from an onsite station, owned and maintained by Northern Water staff. It is located over turf grass in a rural setting. All sensors are re-calibrated each year.

Figure 15 provides an example of the crop curve used for Zone 1 during 2015. Included are Kcb, Kcb x Ks, and final Kc or Kc actual curves. The beginning point for the vegetative growth period on the crop curve timeline was determined each year based on the average air temperature for the previous 30 days. Afterwards, growing degree days were summed to determine the beginning of the mid-season stage. The falling off of Kc values towards the end of season was determined by the lowering 30 day average air temperature and frost events.

Summary

Use of the dual Kc method (Allen, 2016) of calculating evapotranspiration enabled direct comparison of the irrigation management provided by each controller against the ‘preferred’ watering calculated by the soil moisture depletion/balance spreadsheet. Differences in actual evapotranspiration were realized from increased wet surface evaporation following irrigation events, particularly when more frequent irrigations increased the number of ‘wet’ days. Additionally, actual evapotranspiration decreased when soil moisture depletions increased and resulted in plant water stress.

Despite the long duration of this demonstration (two seasons) the controllers were generally able to maintain adequate soil moisture to preserve plant health. Soil moisture depletions exceeded the maximum depletion target by only minor amounts and occurred infrequently. Two exceptions were Controller B in late May 2016 (see Figure 10) and Controller D in late September 2015 (see Figure 6). No clear explanation for either has been determined. Controller D has a rain delay sensor but no measureable rain was recorded during either time period.

It would appear that seasonal crop curves were not utilized by the controllers. This is particularly evident for controller C in 2015 (see Figure 16). Soil moisture levels were generally high in the spring and fall periods when evapotranspiration demand was low. However, during mid-summer when both reference ET and the plant vegetative factor were highest, the controller struggled to keep up. Significant soil moisture depletions remained following every irrigation event but one until early October (timely precipitation helped). The use of seasonal crop curves would improve landscape plant health and appearance during the peak use months of July and August. Additionally the risk for plant loss (permanent wilting) could be avoided and desired landscape benefits preserved. Weather based smart controllers could then operate over longer time periods without needing intervention.

The proper utilization of smart irrigation controllers has great potential to achieve significant water conservation in urban landscapes.

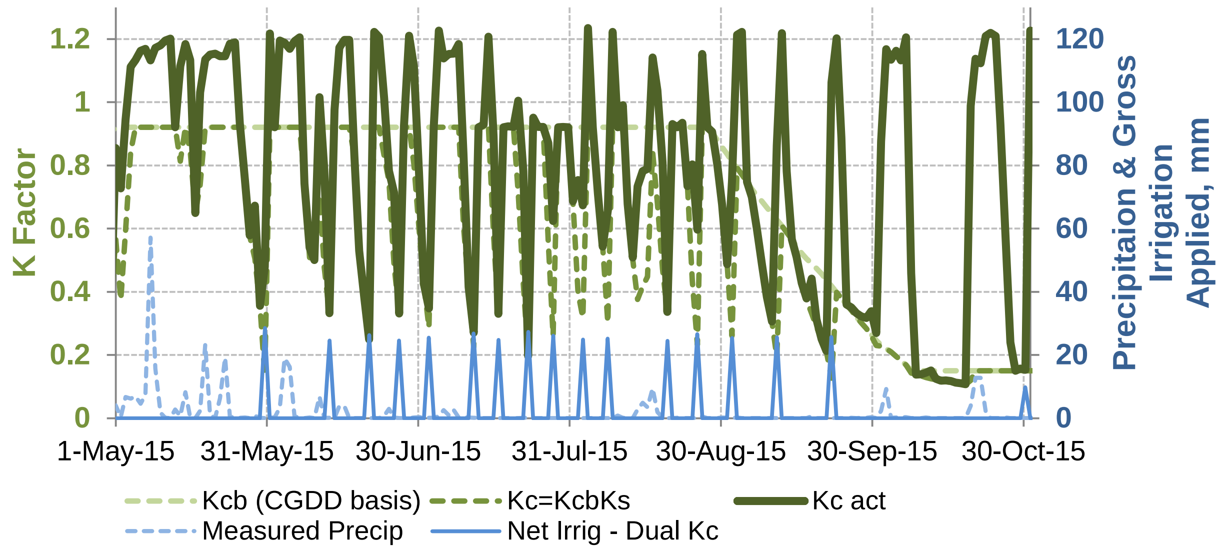

Figure 15. Crop curve coefficients for Zone 1 during 2015 season at Berthoud, Colorado.

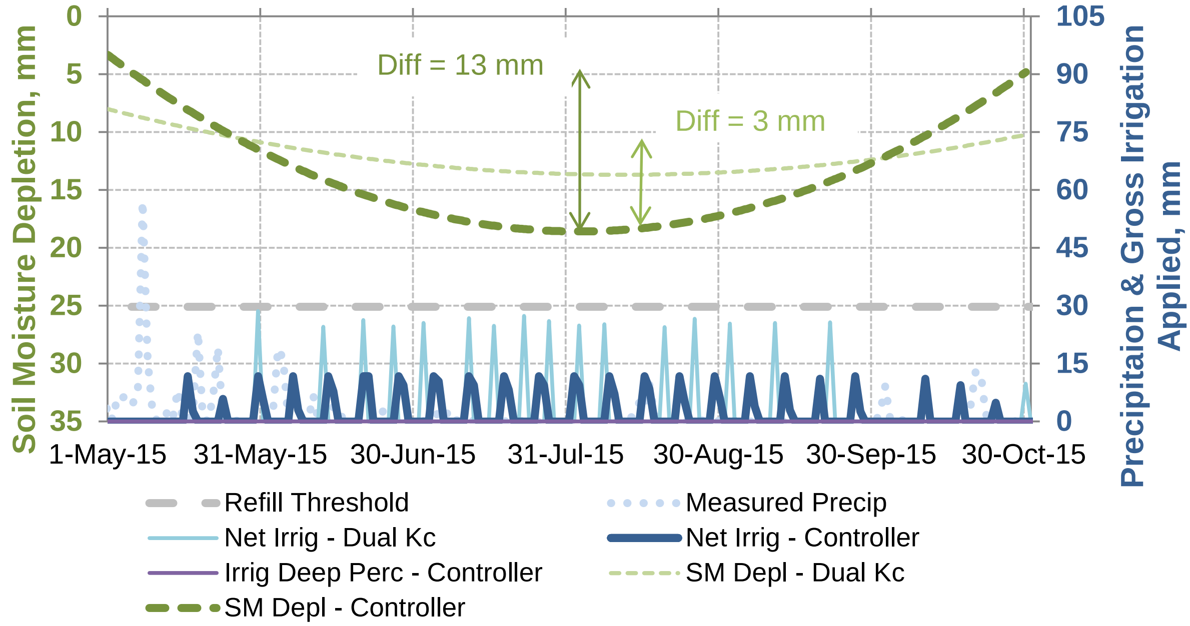

Figure 16. Polynomial regression of soil moisture depletions for Controller C - Zone 1 during 2015 season at Berthoud, Colorado.

References

Allen, R. G. et al. 2005. The ASCE Standardized Reference Evapotranspiration Equation, ASCE, Reston,VA.

Allen, R.G. and M.E. Jensen. 2016. Evaporation from Soil. Chapter 9 in Evaporation, Evapotranspiration, and Irrigation Water Requirements, 2nd ed., ASCE Manuals and Reports on Engineering Practice No. 70, pp.221-259, ASCE, Reston,VA.

Allen, R.G. and M.E. Jensen. 2016. Crop Coefficient Method. Chapter 10 in Evaporation, Evapotranspiration, and Irrigation Water Requirements, 2nd ed., ASCE Manuals and Reports on Engineering Practice No. 70, pp.221-259, ASCE, Reston,VA.