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Tools for Turfgrass Irrigation Water Management

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Increasing competition for water in North Carolina will require improvement in the water management of turf and landscape irrigation. Water-use restrictions have recently been enacted in several North Carolina municipalities. Installation of residential and commercial irrigation systems is on the increase in the state. All of these trends point to a need to use "smart" irrigation technologies and techniques to prevent water waste.

With most buried irrigation systems, irrigation events and durations are controlled with an irrigation-control clock. While these controllers are set to apply a certain amount of water at a certain time, numerous calculations must be done to achieve the correct controller settings, and changes must be made as the turf's water demand changes. Applying the correct amount of water requires not only that the water demand of the turf be known, but also the application rate of the irrigation system. Most homeowners and operators of these systems know neither. To complicate matters, irrigation scheduling (when and how much to water to apply) in humid regions such as North Carolina is difficult due to unpredictable rain events.

Because buried irrigation systems have high investments costs, it is important that these systems are used to maximize their benefit, applying the proper amount of water at the proper time, thereby keeping turf healthy while using no more water than necessary. The dual objectives of conserving water and preserving turf quality suggest that the use of controllers that incorporate "smart" technology holds promise for turf irrigation.

There are a number of commercially available tools to help with turf and landscape irrigation water management. They can be broadly separated into two categories — those that use feedback from a sensor that monitors the amount of moisture in the root zone and those that use weather data to estimate the amount of water used by the turf to adjust irrigation.

The irrigation industry calls these tools "Smart Water-Application Technology" or SWAT. These systems are more prevalent in the western United States, and some water utilities in California are offering vouchers or rebates for customers who purchase approved SWAT technology.

WEATHER-BASED CONTROLLERS

Irrigation controllers based upon weather data, also referred to as "ET" controllers, use weather data to adjust the amount of water applied as the turf's demand for water changes. As the name implies, ET controllers estimate evapotranspiration (ET) of the turf. ET is the total amount of water used by the plant (transpiration) and by evaporation from the soil and plant canopy.

Most ET controllers collect "real time" weather data and update the estimated ET daily or even hourly. The data is obtained either from local weather stations via phone line or satellite, or from on-site measurements taken by simple weather instruments supplied with the controller. Other variations of ET controllers base their system upon long-term historical weather data and may adjust the long-term average ET to current conditions using an on-site temperature sensor. Some systems factor in on-site rainfall, while others consider general rainfall patterns in the area.

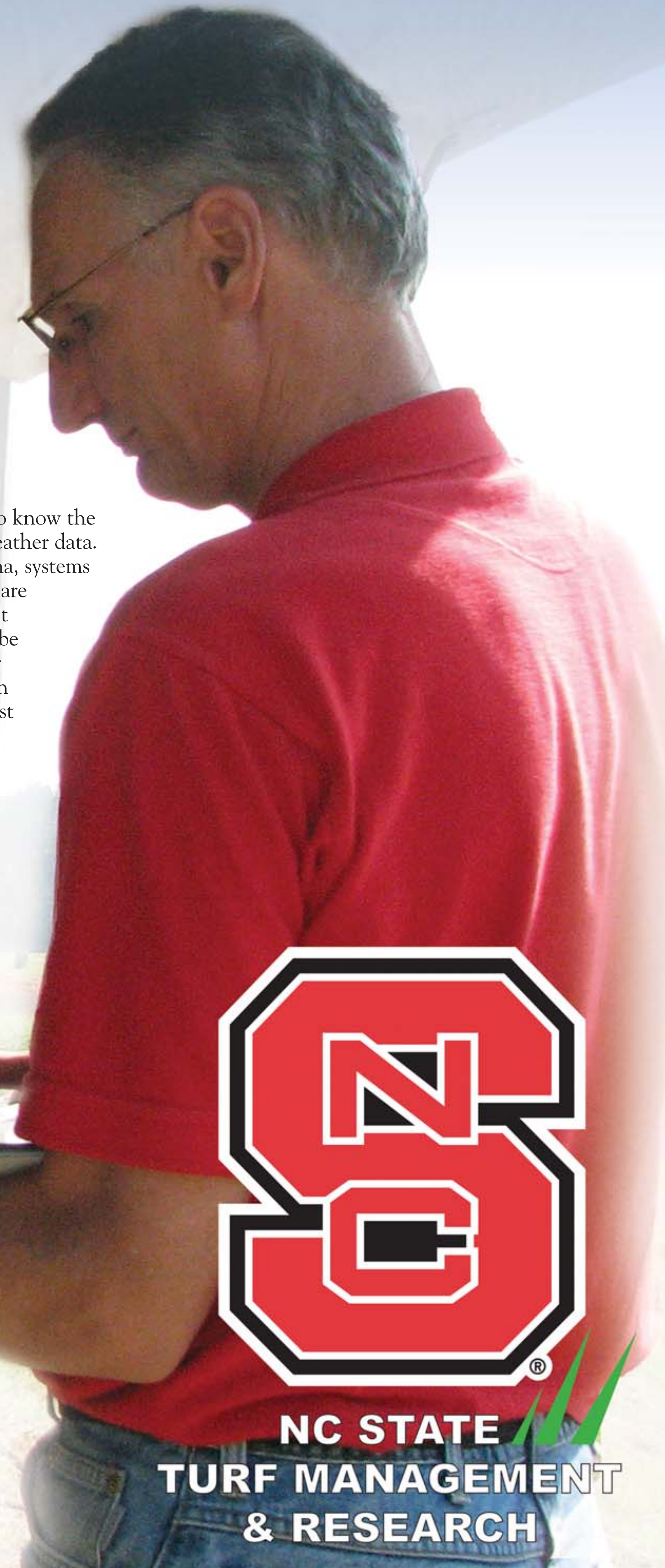
Ease of setup and operation of ET controllers range from fairly easy to complex. Depending upon the controller, users may be required to input a variety of information, including: the type of turf or landscape to be irrigated; specifications of the irrigation system, such as sprinkler type or application rate, and application efficiency; and site conditions, such as shading and ground slope.

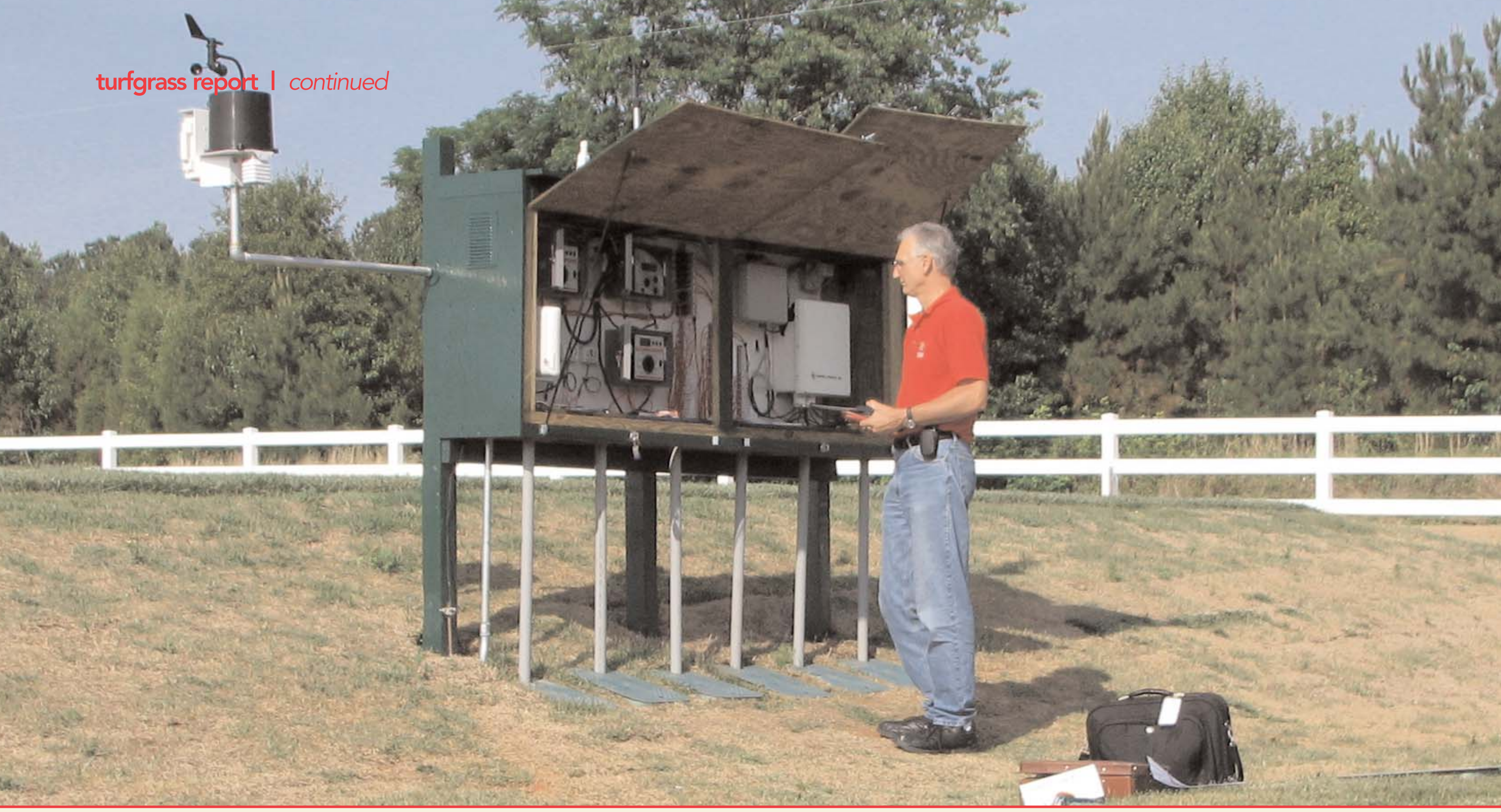
Using the supplied system and site information and weather data, ET controllers run a "water balance" that keeps track of how much water is in the soil. The basic operation of these controllers is to adjust the run times at each irrigation event, thereby adjusting the amount of water applied to the turf. An ET controller operates most efficiently when set in an "automatic mode," in which case the controller itself will select the appropriate days to water. Users can also enter schedules that prohibit watering on specific days, such as those associated with local watering restrictions.

When selecting one of these systems, it is important to know the flexibility of the controller, and from where it collects weather data. In areas of highly localized rainfall such as North Carolina, systems that collect local rainfall data have an advantage. There are many manufacturers of these systems, which vary in cost depending upon the number of irrigation zones that can be served, programming features and any associated weather sensors. For systems that use communication systems such as satellites to retrieve weather data, there is also a modest monthly or annual fee.

SOIL-MOISTURE-BASED SYSTEMS

Systems based on soil moisture use feedback from sensors placed in the soil to adjust watering. In theory, these systems integrate the elements of a water balance into one measurement — the amount of water in the soil. The simplest type of soil-moisture-based





Dr. Garry Grabow at the shed that houses the "smart" technology systems being evaluated. On the site are forty 13′ X 13′ fescue plots irrigated with pop-up spray heads.

Two of the systems being evaluated have moisture sensors like the one in this photo (here, Dr. Grabow is "adjusting" the "on-demand" system).

system is an "add-on" system that is added on to a standard irrigation-control clock. Such systems came on the marker about ten years ago. They comprise a soil-moisture sensor and a module with user interface. In operation, the clock is programmed to irrigate as normal, and the sensor is used to override a scheduled irrigation if the soil is too wet. This "too wet" setpoint level may be adjusted by the user.

Some systems use a somewhat arbitrary scale of wetness (e.g., 1–10), while others let the user specify a soil-moisture level by entering a volumetric soil-water content (percent water by volume of soil), above which any pre-scheduled irrigations will be disabled. To set the setpoint of these systems, the soil is saturated (e.g., by a garden hose or sprinkler) and then allowed to drain for a period of time (usually one day for medium- to heavy-textured soil and perhaps 12 hours for a sandy soil). This establishes the "field capacity" of the soil, or the amount of water held by the soil against gravity. The setpoint is normally set to 75% of the water content at field capacity. Adjustments to the setpoint can be made at any time as required. Some manufacturers of soil-moisture-based systems also sell units with controllers, rather than just the "add-on" sensor with module.

In more sophisticated soil-moisture-based systems, "on-demand" irrigation can be achieved. Two levels of soil moisture can be set — a lower setpoint to initiate irrigation and a higher setpoint to terminate irrigation. Soaking cycles (when irrigation is temporarily halted) can be used to allow the water to reach the sensor so that over-irrigation does not occur. Watering windows can be programmed to allow for constraints such as watering-day restrictions.

"On-demand" systems are complete systems, unlike the add-on systems, and may have a number of added features. These include system monitoring of flow rates and electrical-current usage to warn of any potential irrigation system problems, as well as the ability to add multiple moisture sensors that can be assigned to control any zone(s) the user specifies. Software interfaces and remote communication options are available with these more sophisticated systems.

COSTS

Most ET controllers range from $300 to $500, depending upon the number of irrigation zones they control, the level of sophistication and on-site weather sensors (if any). The most expensive ET-based systems provide flow monitoring and a software interface and cost up to $4,000.

The cheapest of the "smart technologies" are the add-on soil-moisture-based systems, starting under $200. Soil-moisture-based systems that have their own controller are slightly more expensive and depend upon the number of zones they can control.

The most expensive soil-moisture-based technologies are the "on-demand" systems. The cost depends upon whether or not they are retrofitted to existing systems or installed in a new system. When installed with a new system, all sensors and valves are part of a "two-wire system," eliminating the need for separate wiring of each zone. When installed in existing irrigation systems, "zone adapters" are required to allow the system to emulate a two-wire system that allows communication between the sensors and the solenoid valves. These controllers cost about $2,500, not including the zone adapters.

The more-expensive systems are not targeted to homeowners but to commercial turf and landscape irrigation. Reduced pricing is generally available to contractors for all systems.

RECENT RESEARCH

Three "smart" systems are being evaluated at NC State University by the Dept. of Biological and Agricultural Engineering (Drs. Garry Grabow and Rod Huffman) and the Dept. of Crop Science (Drs. Dan Bowman and Grady Miller). A study site with forty 13' X 13' plots sod in tall fescue and irrigated with pop-up spray heads was installed in fall of 2006. One season's worth of data has been collected for an ET controller and two soil-moisture-based systems (an add-on system and an "on-demand"

(Right) A soil-moisture probe being installed in one of the study plots, about 5" below the soil surface.

Table 1. Total Applied Water in Inches from April 22 to September 8, 2007 (20 weeks).

Technology	Irrigation Frequency, days per week		
	1	2	7
Timer[1]	16.88"	16.92"	15.62"
Add-On[2]	8.56"	12.81"	13.87"
On-Demand[3]		17.64"	
ET[4]	16.27"	24.54"	25.66"

[1] Standard irrigation control clock set to replace long-term average irrigation requirement with added rain sensor.
[2] "One setpoint" add-on system with soil-moisture sensor and module added to standard timer.
[3] "Two setpoint" on-demand stand-alone system with soil-moisture sensor.
[4] ET controller with rain sensor added.

system). These systems are being compared to a standard irrigation-control clock set to replace the long-term average irrigation requirement.

Irrigation frequency is also being evaluated in this study. All systems except for the "on-demand" system are set to water daily, twice a week and once a week. Turf quality is being assessed by a visual rating system, and turf-canopy temperatures are being recorded to monitor moisture stress.

Total applied water in inches for the 20-week duration of the study in 2007 is presented in Table 1. These amounts factor in an irrigation system efficiency of 80%, which roughly means that, on average, the net irrigation amount (water received by the turf) was only 80% of the applied amount.

This past summer was hotter and drier than normal, so the net amount of water applied by the timer treatment (long-term average irrigation requirement) was below that required for full irrigation of fescue. The estimated turf water requirement over the course of the 20-week study was 20.9", assuming a crop coefficient of 0.8. The crop coefficient is multiplied by the "reference ET" to estimate the water requirement of a specific "crop," in this case tall fescue. A crop coefficient value of 0.8 is commonly used for a cool-season turf such as fescue.

The reference ET was estimated using the Penman-Monteith equation and weather data collected on-site. Although 11.4" of rain fell during the 20-week study period, less than half that amount was usable, since much of the rain came in unevenly distributed intense thunderstorms, and only a portion was stored in the root zone.

The last half of June and the first half of July were particularly hot and dry, so the plots irrigated by the standard irrigation-control clock and by the soil-moisture system added to a standard control clock did not receive the amount of water the plots demanded. Turf quality was best for plots irrigated with the "on-demand" system and the ET controller system. **The "on-demand" system provided the best combination**

of efficient irrigation and turf quality, and this was the most expensive system tested.

While the plots irrigated by the ET controller at twice-a-week and daily intervals had high turf quality, more water was applied than the "on-demand" system that provided equal turf quality. In general, plots watered only once a week had poorer turf quality than those watered twice a week or daily.

The study is planned to continue for two more years so that longer-term trends in performance can be assessed.

Reducing water application through the use of these technologies may expose poorly designed irrigation systems (poor uniformity), and these "smart" systems will not solve problems due to poor irrigation-system design.

One easy, effective and inexpensive way of reducing water used by turf and landscape irrigation is to install a rain sensor. In regions of high rainfall, this can result in substantial water savings by simply preventing irrigation during or immediately after a rain.

CONCLUSIONS

"Smart" irrigation technologies hold promise for efficient irrigation, thereby conserving water while maintaining healthy turf. However, these systems are not a "magic bullet," and setup and adjustments by a landscape professional may be required, especially for the weather-based (ET) controllers. Setup, monitoring and adjustment are especially important if the dual goals of water conservation and acceptable turf quality are to be met.

Dr. Bir Thapa will use a soil-moisture probe to record moisture in all forty plots. The probe is lowered into a 1" diameter access tube and measures moisture at several depths.