ET Networks and the Protection of Groundwater Supplies and Quality

White Paper Prepared by the Texas Groundwater Protection Committee (TGPC)
Groundwater Issues (GWI) Subcommittee

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Executive Summary

Evapotranspiration (ET) is a key parameter used in the management of both agricultural and urban irrigation, commonly referred to as irrigation scheduling. The purpose of proper irrigation scheduling is to apply only the amount of water needed by the crop or plants at that point in time. Applying excess water wastes limited groundwater resources, and the resulting runoff and deep percolation carries water-soluble fertilizers, pesticides, and herbicides which can make their way into aquifers. Without ET data, irrigation decisions are often made using non-scientific methods resulting in excessive amounts of runoff and deep percolation. ET is also used in many other applications including water planning, drought mitigation, and the design of certain civil works. Accurate ET data is particularly important in water application permitting, including the application of reclaimed water (i.e., wastewater). There is concern about the accuracy of currently available data that is used to determine permitted wastewater application volumes. ET is calculated using special weather stations which are equipment with solar radiation sensors, among others. Solar radiation is not recorded by the National Weather Service. Currently, Texas has only one ET Network, the TexasET Network, which exists as a partnership between local sponsors and the Texas A&M Agrilife Extension Service. This network has no dedicated source of funding and its long-term viability is in doubt. In addition to locally-sponsored weather stations, the TexasET Network is accessing weather data from the TexMesonet (a general-purpose weather station network) in order to make ET available statewide. A closer partnership between the TexasET Network and the TexMesonet is one option for ensuring the long-term sustainability of providing ET data to the people of Texas.

Acronym List

ASCE – American Society of Civil Engineers
CAFO – concentrate animal feeding operation
cm – centimeter
ET – evapotranspiration
ETo – reference evapotranspiration
FAQ – Frequently Asked Question
PET – potential evapotranspiration
TAC – Texas Administrative Code
TCEQ – Texas Commission of Environmental Quality
TWDB – Texas Water Development Board
WCAC – Water Conservation Advisory Council

Introduction

This paper provides a short overview of the role of evapotranspiration (ET) in the protection of groundwater quality and quantity, and issues related to ensuring the long-term sustainability of providing ET data in Texas via an ET Network. There is a recent report which was produced for the Texas Water Development Board (TWDB) that provides a detailed and thorough discussion of ET Networks, their benefits, and options to establish a sustainable network for Texas (see Nielsen-Gammon et al., 2017). Much of the information included in this paper is from this report. Additional data is provided by the Texas Commission of Environmental Quality (TCEQ) Water Quality Division.

Full Issue Information and Discussion

Texas climate is characterized by extremes, and agriculture depends on reliable timing and availability of water. Plants need water for photosynthesis where it is exchanged for atmospheric carbon and used to build biomass. As crops grow, water in the root zone is depleted, leading to stress and reduced productivity. Irrigation is often used to supplement rainfall and increase soil moisture storage. Irrigation is the largest category of water consumption in the State, using 7.83 million acre-feet in 2014, with 82% of that coming from groundwater (TWDB, 2017). Municipal water use is the second largest category of water use in Texas after agricultural irrigation and is quickly rising, and landscape irrigation accounts for 40-60% of municipal water consumption during the lawn irrigation season. While estimates vary, it's likely that excessive irrigation accounts for 30% of agricultural irrigation and 50% of urban irrigation.

ET is a key parameter used in the management of both agricultural and urban irrigation, commonly referred to as irrigation scheduling. Proper irrigation scheduling is basically applying just the amount of water needed by crops and plants based upon the local climate and certain site-specific characteristics (i.e., soil type, rooting depths, and irrigation system performance). Use of ET for proper irrigation scheduling is widely promoted by state agencies, water districts, cities, and utilities and has been proven to prevent excessive irrigation. ET-based irrigation schedules are required in many federal agricultural support programs and by the Texas Commission on Environmental Quality (TCEQ) for new landscape irrigation designs. ET is also a key component of water application permitting decisions by the TCEQ and water districts, including the application of wastewater. ET is used in the generation of the required water balance calculations which determine the permitted wastewater application volume appropriate for a site.

Applying excess water wastes limited groundwater resources, and the resulting runoff and deep percolation carries water-soluble fertilizers, pesticides, and herbicides which can make their way into aquifers. The most vulnerable aquifer in Texas to such contamination is the Edwards Aquifer, because surface waters can directly enter this karst aquifer with little attenuation. Deep percolation refers to the movement of water through the soil and is the primary means of recharge of most of Texas' groundwater. This recharge, however, can carry pollutants and affect groundwater quality.

Defining ET

ET is the conversion of liquid water to vapor from the soil and through transpiration by vegetation. The amount of ET that takes place when a plant is growing optimally at a given time and place is that plant's ET requirement. While originally developed for agriculture, the ET concept has been adopted to cover most plant materials, including landscapes, athletic fields, plant nurseries, etc. The ET requirements depend upon the type of plant, its current growth stage, the local climate, and other factors. Potential or reference evapotranspiration (written as PET or ETo) is the amount of water used by a reference crop assuming no limits of soil water availability. ETo assumes a hypothetical reference crop with very fixed parameters (e.g., 12 cm tall, fixed surface resistance, 0.23 albedo, etc.). ETo is the maximum amount of atmospheric demand for water required by the reference crop given local climatic conditions. The reference crop, usually a cool season grass or alfalfa, is assumed to be well maintained with growth not limited by water availability, nutrients, disease, etc. (Jensen and Allen, 2016).

In 1999, the American Society of Civil Engineers (ASCE) formed a Task Committee on Standardization of Reference Evapotranspiration. The resulting method is often referred to as the ASCE standardized equation and has been adopted world-wide (Jensen and Allen, 2016). Integral to the calculation of ETo with the standardized method is the accuracy of the climatic data required (i.e., temperature, relative humidity, solar radiation, and wind). Siting requirements for ET stations are often much stricter than that of weather stations used in other applications.

ET and Wastewater Permitting

In Texas, the TCEQ has permitted the application of approximately 265,816 acre-feet/year of water, including water for crop production from regulated domestic septage, water treatment plant sludge, concentrated animal feeding operations (CAFOs), industrial wastewater, and municipal wastewater operations (Table 1). The application of this volume of liquid is regulated via 30 Texas Administrative Code (TAC) 309; 30 TAC 222; 30 TAC 312 and 30 TAC 321. These regulations require the use of water balances (30 TAC 309.20) to ensure that the amount of water applied to the crops from these operations does not exceed the crop needs, thus avoiding potential discharges to either surface or groundwater. The water balance is also used to calculate the storage capacity needed to hold water from the year with the highest rainfall and the year with the lowest ET in the last 25 years of record.

Table 1. TCEQ water application permits and annual volumes.*			
Type of Permit	Number of Sites	Volume	
		gallons/yr	ac-ft/yr
Domestic Septage**	47	202,743,184	622
WTP**	122	7, 118,000,000	21,844
CAFO GP	502	28,027,750,367	86,014
CAFO IP	48	980,229,878	3,008
Industrial WW	82	19,508,983,348	59,871
Municipal Public Domestic WW	246	27,649,356,995	84,852
Municipal Private Domestic	110	3,105,047,591	9,529
RO Reject Land Application	3	24,820,000	76
Total	1160	79,296,188,179	265,816

yr: year
ac: acre
ft: foot
WTP: Water Treatment Plant sludge
CAFO GP: Concentrated Animal Feeding Operation General Permit
CAFO IP: Concentrated Animal Feeding Operation Individual Permit
WW: wastewater
RO: Reverse Osmosis
* Source: TCEQ Permit and Registration Information System (PARIS) database
** Permit applications for domestic septage and water treatment sludge do not require a water balance from the applicant, but TCEQ staff agronomists do occasionally run a water balance during project reviews.

A proper water balance calculation requires accurate long-term rainfall and evapotranspiration (ET) data, normally in units of inches of water per month. The three most common references for ET used for these calculations are Bulletin 6019 (McDaniels, 1960), Borelli et al. (1998) and the TexasET Network. However, the ET values from these sources differ significantly from each other, with the values generated from the TexasET Network considered the most accurate. For example, Table 2 compares ET values for pasture obtained from these three sources for Travis County. The Borelli report significantly exceeds ET rates developed from 21 years of TexasET Network data (2000-2020), as does Bulletin 6019 for all months except December, January and February.

Table 2. Comparison of ET values (inches) for grass in Travis County from three sources that are commonly used for TCEQ permitting.													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bulletin 6019	0.81	1.17	2.79	3.42	6.12	6.48	6.66	4.59	5.13	4.05	2.07	0.99	44.2
Borelli's Report	2.60	2.79	4.23	4.74	5.17	5.99	7.14	6.54	5.47	4.10	2.90	2.39	54.1
TexasET* Network	1.59	1.69	2.56	3.0	3.94	4.60	4.92	4.53	3.08	2.36	1.49	1.25	35.0

* Values were calculated using a crop coefficient of 0.7 and the actual record of ETo data from the TexasET Network for Austin from June 2000 to June 2020.

Small differences in ET values result in large errors in setting appropriate application volumes for a particular site. With a state-wide ET Network, long term averages of actual ETo could be developed for multiple locations in Texas, greatly improving the water permitting accuracy by reducing the reliance on out-of-date data such as found in Bulletin 6019. In the absence of a more accurate (closer to the true value) and precise (reproducible value) set of ET values, the potential for contamination of surface water via runoff and contamination of groundwater via seepage and percolation increases because volumes greater than what the crop needs are being permitted. Sizing of storage volume is also affected by the accuracy of the ET values used. Inaccurate ET values can result in the over- or under-sizing of retention structures such as ponds. It is imperative that a more accurate and precise source of crop ET values be made available for proper management of water use in Texas.

Defining an Evapotranspiration Network

In a Frequently Asked Question (FAQ) document by the Texas Groundwater Protection Committee (TGPC), an ET network is defined as a network with the following characteristics:

1. Consists of special weather stations designed specifically to measure the parameters needed for the calculation of reference evapotranspiration (ETo),
2. Calculates and uses ETo to determine plant water requirements (ET) and irrigation watering recommendations, and
3. Disseminates this information to end users through on-line access, on-line tools, emails, and other methods.

ET Networks in Texas

At one time, Texas had five ET or closely-related networks simultaneously operating in different regions of the state. However, all but the TexasET Network have since ceased operation due to funding issues. Discontinued networks were programs of Texas A&M Agrilife Research and include the:

1. Texas High Plains PET Network,
2. Crop Weather Program for South Texas,

3. Precision Irrigators Network, and
4. South Texas Weather Network.

There are two major mesonets in Texas which report ETo data but do not fit the definition of an ET Network as given above. A mesonet is a general-purpose weather station network whose stations have additional sensors than what is required for ETo and those sensors are at different heights than what is required for ETo. However, many of these stations are sited properly for generation of ETo data. These mesonets are:

1. The West Texas Mesonet at Texas Tech University with 134 stations, and
2. The TexMesonet, a program of the Texas Water Development Board, with 75 stations.

There are numerous other weather station and environmental monitoring networks in Texas (See Nielsen-Gammon et al., 2017).

The TexasET Network is the sole network in Texas dedicated to the dissemination of ET data in Texas. The network is a program of the Texas A&M Agrilife Extension Service and it depends upon local sponsors to cover the costs of purchasing, installing, and maintaining the ET stations. The TexasET Network consists of 55 such stations and it is now incorporating data from the subset of 75 TexMesonet stations which meet ET siting criteria.

The TexasET Network has grown significantly in recent years due to the Water My Yard ("*WaterMyYard*") program which received the Water Conservation Advisory Council (WCAC) Blue Legacy Award in 2015. *WaterMyYard* uses ETo data to produce weekly home yard watering recommendations customized for each user's situation. With this program, extensive urban ET networks have been established in the greater Dallas-Ft Worth, Houston, and Austin areas, among other locations by the program sponsors. Sponsors consist of water districts, cities, public utilities, and a river authority. The program currently has about 34,000 users and it is rapidly growing. In 2020, *WaterMyYard* is estimated to have reduced excessive urban irrigation by 1,770 million gallons.

While the larger water districts have dedicated personnel to oversee the operation and maintenance of these stations, there is some concern about the ability of smaller organizations to provide this support over the long-term. Currently, TexasET Network personnel provide technical support to the sponsors, but this will become increasingly difficult as the program continues to expand.

The Future

Nielsen-Gammon et al. (2017) present several options for the creation of a sustainable ET Network for Texas. One of the options is the incorporation of TexasET or TexasET-type capabilities into the TexMesonet. The benefits resulting from such an incorporation include:

1. Future sustainability of a state-wide ET network is assured,
2. The TexMesonet would gain access to a unique and dense urban weather network that has great value in water planning, drought and flood mitigation, and many other applications,
3. The integrity of weather station hardware and data would be assured,
4. The *WaterMyYard* program could be expanded in the state,
5. *WaterMyYard*-type tools for agricultural irrigation could be developed, and
6. Long-term actual ET averages for wastewater and other water permitting applications could be developed.

A Continuing Research Need

- Further development of Texas-specific crop/plant coefficients.

Recommendations

- Establish a sustainable state-wide ET Network to ensure that accurate and precise crop ET values are made available for the proper management of water use in Texas.
    - With a state-wide ET Network, long term averages of actual ETo could be developed for multiple locations in Texas, greatly improving water permitting and planning by reducing the reliance on out-of-date data.
- Identify and provide funding for agencies or organizations that will operate, maintain, and technically support the stations in this network, and that will continue to make available and further develop end-user products and on-line tools for the dissemination of ET data.
    - A closer partnership between the TexasET Network and the TexMesonet is one option for ensuring the long-term sustainability of providing ET data to the people of Texas.

TGPC GWI Subcommittee members include, but are not limited to:

- Texas Commission of Environmental Quality (TCEQ);
- Texas Water Development Board (TWDB);
- Railroad Commission of Texas (RRC);
- Texas Department of State Health Services (DSHS);
- Texas Department of Agriculture (TDA);
- Texas State Soil and Water Conservation Board (TSSWCB);
- Texas Alliance of Groundwater Districts (TAGD);
- Texas A&M AgriLife Research (AgriLife Research);
- Bureau of Economic Geology of The University of Texas at Austin (UTBEG);
- Texas Department of Licensing and Regulation (TDLR);
- Texas Parks and Wildlife Department (TPWD);
- Texas Tech University (TTU);
- Texas A&M AgriLife Extension Service (AgriLife Extension); and,
- United States Geological Survey (USGS).

The primary goals of the TGPC GWI Subcommittee are to:

- Facilitate interagency communication for assessment programs addressing groundwater contamination;
- Coordinate and assist member agencies with monitoring programs for:
    - Ambient groundwater conditions;
    - Pesticides; and,
    - Emerging contaminants or constituents of concern;
- Support the intent of the *Texas Groundwater Protection Strategy* (https://www.tceq.texas.gov/assets/public/comm_exec/pubs/as/188.pdf) by:
    - Reviewing published data reports, and evaluating data independent of published reports, to assist in the determination of the effectiveness of existing regulatory programs and to identify potential groundwater contaminants not addressed by existing regulatory programs;
    - Developing recommendations for consideration by the TGPC to address potential groundwater contamination identified through monitoring and data review; and,
    - Developing white papers on the groundwater issues listed in their biannual *Activity Plan* which summarize the best available scientific data on a specific groundwater issue, identify areas where there is insufficient scientific data to thoroughly assess the issue, evaluate the effectiveness of existing regulatory

programs to address the issue, and provide recommendations or policy options to the TGPC regarding the issue.

The above recommendations or policy options represent the opinion of the TGPC GWI Subcommittee and do not necessarily reflect the views and policies of each participating organization. The United States Geological Survey (USGS) may have contributed scientific information, only.

For more information about this white paper, please contact the TGPC (https://tgpc.texas.gov/contact-us/).

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