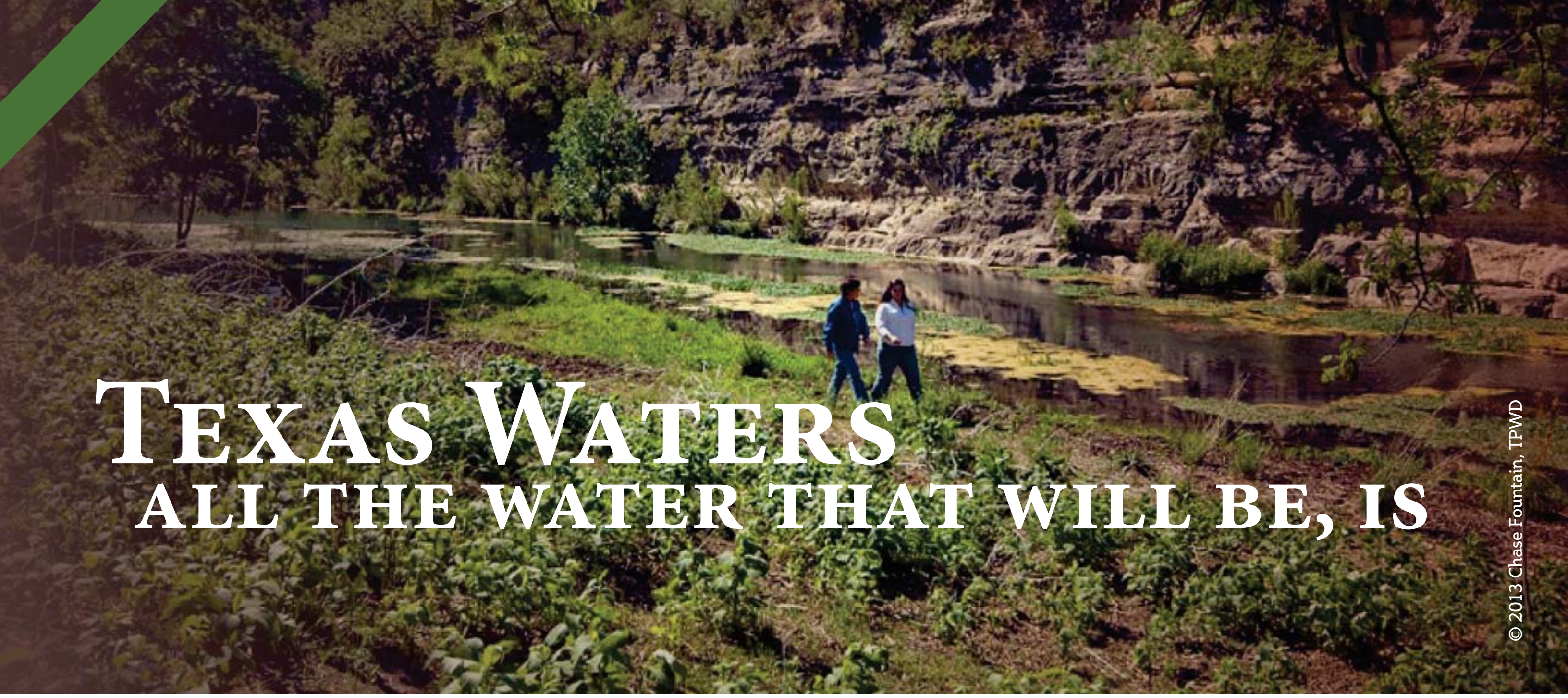


Jessica Vandivier (r) and Ann Vandivier Brodnax on South Llano River, Llano Springs Ranch. TWA Director Tom Vandivier was the 2008 Lone Star Land Steward Winner, Leopold recipient, Hill Country.

A Water Primer

ARTICLE BY HENRY CHAPPELL

EDITOR'S NOTE: *This is the first installment of a quarterly column on water in Texas.*

In *Water Follies: Groundwater Pumping and the Fate of America's Freshwaters*, author Robert Glennon attributes this elegant, but not-quite-obvious truth to an anonymous observer. From a general perspective, one could also assert that "All the water that is, will be." Or, more precisely, "All the water molecules that are, will be."

We can think of earth's water cycle, or "hydrological cycle," as a closed system. Per the Law of Conservation of Matter, natural forces and human activity can't create or destroy water. Rather, they move it around or contaminate it, often making it unavailable or unfit for immediate use.

Plants and animals do not consume water; they use it, then return it. We must take in water to live, but we also sweat, produce waste, and, as anyone who has ever exhaled onto a cold window pane knows, we release water vapor into the atmosphere every time we exhale. When we die, our remains desiccate. The water molecules leave the dead tissue but remain in the hydrological cycle.

While water cannot be fully consumed or destroyed, it can be rendered inaccessible or unusable. For example, some percentage of groundwater pumped from a desert aquifer and used for irrigation will be returned to the atmosphere through the process of transpiration and evaporation. Much of that moisture may then be carried eastward by winds to fall as rain over the Gulf of Mexico. So, while water drawn from the aquifer is still in the hydrological cycle, it's no longer immediately available to desert growers. If that aquifer's recharge rate is slow or nil, as it's likely to be in an arid region, the growers are depleting their water source every time they turn on their pumps.

Oceans cover about 70 percent of earth's surface and, thus, absorb most of the sun's energy. Solar heating of the oceans causes evaporation. Water vapor rises into the atmosphere, leaving behind the salt. Wind currents carry this moisture landward, where it increases relative humidity, causing precipitation in the form of rain, snow, or hail. As precipitation reaches the land, evaporation begins anew. Although evaporation rates vary drastically with location, about 50 percent of all precipitation returns directly to the atmosphere.

Of the remaining 50 percent, a substantial amount returns to the atmosphere indirectly through transpiration by trees and other rooted vegetation. Some of the precipitation flows over the land as runoff. Under force of gravity, which draws water toward the lowest elevation, some runoff makes its way into rivers, creeks and other drainages, and eventually back to the ocean. Finally, a significant portion of precipitation percolates into the ground to recharge groundwater supplies. If left unused, this water may remain in underground reservoirs – aquifers – for years, or even millennia.

Less than 1 percent of earth's water is drinkable or "potable." Oceans account for 96.5 percent of our planet's water. Of the remaining 3.5 percent, about 1 percent is brackish – less saline than seawater but still too salty to drink. Currently, about 1.7 percent takes the form of polar ice. That leaves only 0.8 percent in the form of rivers, streams, lakes, marshes and groundwater – fresh water available for use by humans and wildlife.

Worldwide, there is 30 times more potable water underground than in all of the earth's rivers, lakes, and other sources of potable surface water.

Texas is remarkably diverse, covering 10 distinct ecological regions. These vary in character, from the cypress bayous of deep East Texas to the Chihuahuan Desert in far West Texas; from the Gulf

Coastal Marshes, beaches, and barrier islands, to the High Plains shortgrass prairie in the Panhandle.

This variation reflects vast differences in average rainfall, from more than 55 inches per year at Port Arthur near the Texas-Louisiana border, to less than 10 inches per year at El Paso. Precipitation increases west-to-east approximately 1 inch per 15 miles. Precipitation, along with geological history, account for the quantity and forms of surface water and groundwater in each region.

Temperature influences both rate of evaporation and transpiration by plants. Usable water – water available for use by humans and wildlife – is precipitation leftover after evaporation and transpiration. "Evapotranspiration," is the sum of evaporation and transpiration. All other things equal, the higher the temperature, the higher the rate of evapotranspiration. Air temperature, surface temperature, atmospheric humidity, sunshine, and wind all significantly affect the rate of evapotranspiration.

Potential evapotranspiration (PET) is the amount of water that could be evapotranspired, if it were available. Actual Evapotranspiration (AE) is the actual amount evapotranspired. Thus, annual PET in the El Paso area, with its low humidity and hot summer days and high wind speeds, averages 114 inches, even though mean annual precipitation is only 10 inches. In sweltering, humid Houston, annual PET averages less than 79 inches. We care about PET, because it is the amount of water needed for optimum plant growth. Roughly speaking, then, the amount of irrigation needed in a given area over a given period of time can be estimated by subtracting the amount of precipitation from PET, assuming a normal year in which PET exceeds precipitation.

Fluctuations in temperature and precipitation make precise irrigation planning (and water planning, in general) impossible. Texas is a state of extremes. Drought and flooding are common. Precipitation fluctuation, as a percentage, tends to increase in a westward direction.

Surface water takes the form of rivers and streams, as well as natural and manmade reservoirs.

Fifteen major river systems flow through Texas. Eight of these – the Nueces, San Antonio, Guadalupe, Lavaca, Brazos, San Jacinto, Trinity, and Neches – run their entire course within the state. Seven rivers nourish bays and estuaries on the Texas coast: the Sabine and Neches Rivers flow into the Sabine-Neches estuary (Sabine Lake); the Trinity and San Jacinto feed the Galveston Bay system; the Colorado and Lavaca end at Matagorda and Lavaca bays; the Guadalupe and San Antonio Rivers feed the Guadalupe Bay, San Antonio Bay, and Espiritu Santo Bay; the Nueces River flows into Nueces and Corpus Christi Bays.

The Red River, which rises in Curry County, New Mexico, forms the Texas-Oklahoma border for some 200 miles. The Canadian River rises in Sangre de Cristo Mountains in Colorado, crosses the Panhandle, and flows into Oklahoma, where it merges with the Arkansas River. The Rio Grande flows from its headwaters in San Juan County, Colorado, through the middle of New Mexico, and, beginning at El Paso, forms a nearly 1,000-mile border with Mexico, before flowing into the Gulf of Mexico at Brownsville. The Pecos River runs from its headwaters on the western slope of the Santa Fe mountain range, in New Mexico, to its confluence with

Although the devastating drought of 2011 left this large stock tank dry, the water that had been there remains in the earth's hydrological cycle – a fact that brings scant comfort to West Texas ranchers. Photo by Wyman Meinzer

All other variables equal, the higher the temperature, the higher the evaporation rate. Thus, over the course of a year, the water in this stretch of river in Texas's semi-arid Rolling Plains region will evaporate faster than water in a New England stream. Photo by Russell Graves

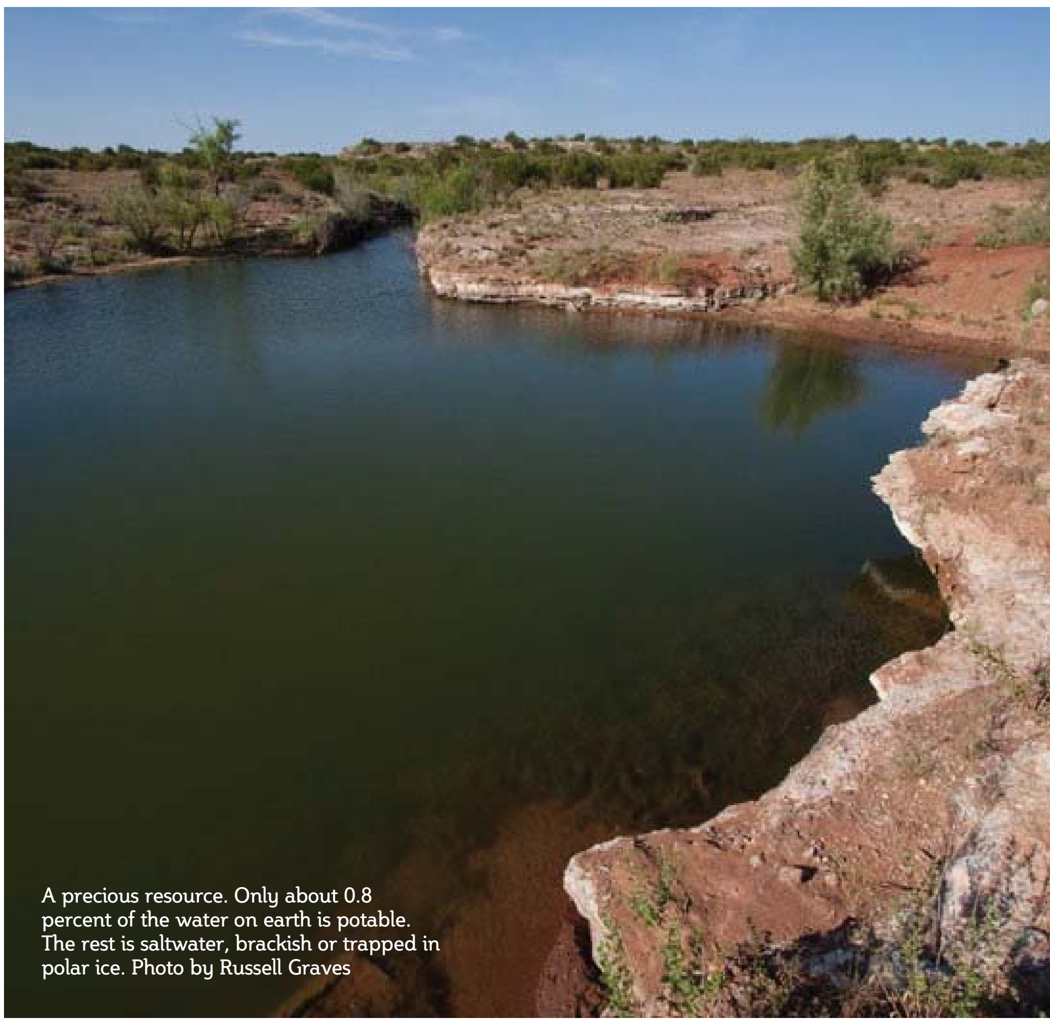
the Rio Grande, northwest of Del Rio.

In total, counting all of the tributaries of these major drainages, Texas holds some 3,700 named rivers and creeks, totaling about 80,000 miles, and draining about 49 million acre-feet of water per year.

Along these thousands of miles of flowing water, 212 major reservoirs and over 5000 smaller reservoirs cover 1.2 million acres and provide some 60 million acre-feet of water storage.

Despite its droughty reputation, Texas ranks second in the nation, behind Minnesota, in total area covered by lakes and reservoirs, and it's second to Alaska in total volume of inland water.

Currently, more than half of all water consumed in Texas comes from aquifers. There are nine major aquifers and 21 minor aquifers in Texas. Except for parts of the desert mountain region, or Trans Pecos Region, in far West Texas, east of El Paso, usable groundwater underlies most of the state. These aquifers vary tremendously in capacity and rate of recharge. Some, like the Edward's Aquifer, in Central Texas, recharge rapidly during times of adequate rainfall. Others, such as the giant Ogallala Aquifer, beneath the High Plains, have a recharge rate so slow as to be essentially negligible. Groundwater from these low-recharge aqui-



A precious resource. Only about 0.8 percent of the water on earth is potable. The rest is saltwater, brackish or trapped in polar ice. Photo by Russell Graves

Texas boasts some 80,000 miles of rivers and streams. Only Alaska has more. Photo by Wyman Meinzer

fers is essentially a non-renewable resource; to pump is to mine.

Springs occur where groundwater from saturated aquifers escapes to the surface, usually amid exposed and broken rock along fault lines, such as the 300 mile "spring line" along the Balcones Escarpment in Central Texas and the portion Caprock Escarpment that rises from the Rolling Plains in the southeastern corner of Panhandle. Texas may have as many as 3,000 springs, of which, 1,292 are currently named.

Springs form the headwaters of some of Texas's rivers and streams, and many provide crucial seasonal or year-round flow. Some form critical habitat for rare and endangered species. Because springs are dependent on aquifer levels, legal measures under the federal Endangered Species Act have restricted pumping of certain aquifers.

Short of desalinization of seawater on a currently impractical scale, we will have to make do with the freshwater we have. They aren't making any more of it. In the May 2014 column, we'll examine the political battle fronts formed in response to Texas's limited water supply and growing population.