A Field Investigation of Major Controls on Phreatophyte-Induced Fluctuations in the Water Table

Gerard J. Kluitenberg[1], James J. Butler, Jr.[2], and Donald O. Whittemore[2]

[1]Department of Agronomy, Kansas State University; [2]Kansas Geological Survey, University of Kansas

Introduction

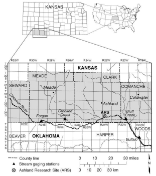
Water-level records from wells screened in shallow aquifers often display fluctuations of varying frequencies and magnitudes. Common mechanisms responsible for short-term (hours to days) fluctuations include cyclical pumping of nearby wells and changes in stream stage or barometric pressure. Longer-term (weeks to years) fluctuations are commonly attributed to variations in climate and anthropogenic water use. Hydrographs from shallow wells in riparian zones with phreatophytes frequently display a distinctive pattern of diurnal fluctuations. Although first linked to variations in plant water use early in the last century, these diurnal water-table fluctuations have received relatively little attention in the literature. In particular, little attention has been given to assessing the major controls on these fluctuations and how best to exploit the information embedded in the water-level records to improve estimates of the hydrologic budgets of shallow aquifers and riparian zones.

Objective

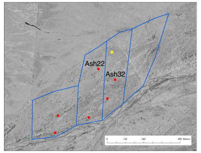
Present results from a multi-site investigation directed at clarifying major controls on phreatophyte-induced fluctuations in the water table and demonstrating ecohydrologic insights that can be gleaned from these fluctuations.

Overview of Field Sites

Ashland Research Site (ARS)



- Located in riparian area along Cimarron River in southwest Kansas near the border with Oklahoma.
- Overlies shallow unconfined aquifer composed primarily of fine to medium sand with varying amounts of silt and clay.
- Major phreatophytes are salt cedar (*Tamarix* spp.) with minor amounts of Russian olive (*Elaeagnus angustifolia*).
- The Cimarron River is located just to the south of plots outlined in blue. The plots are being used to evaluate methods for salt cedar control.

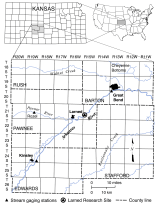


- Six wells (red dots) screened across water table, each with integrated pressure-transducer and datalogger unit submerged in water column.
- Weather station (yellow cross) used to collect meteorological data.
- Water content in vadose zone monitored biweekly during summer using neutron probe in access tube near each well.

Acknowledgments: Funding provided by the Kansas Water Resources Research Institute, the Big Bend Groundwater Management District, and the Kansas Water Office. The assistance of M. Aufman, C. Barden, K. Baum, R. Brauchler, M. Buckley Zeimen, S. Cain, G. Davis, J. Healey, J. Heitman, W. Jin, S. Loheide, S. McKay, R. Newman, J. Uribe, and X. Zhan is gratefully acknowledged.

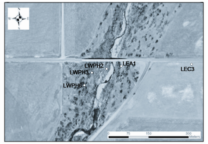
Overview of Field Sites (cont.)

Larned Research Site (LRS)



- Located in riparian area on the Arkansas River near Larned, Kansas.
- Overlies unconfined, course-sand and gravel aquifer in direct hydraulic connection with intermittently flowing river.
- Phreatophyte community consists of cottonwood (*Populus* spp.) with lesser amounts of mulberry (*Morus* spp.) and willow (*Salix* spp.).
- Ten wells screened across water table, each with integrated pressure-transducer and datalogger unit submerged in water column. Data from five wells (white dots) are used in this presentation.

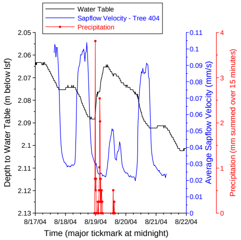
- Meteorological data collected with weather station located in pasture northwest of riparian area (just east of compass symbol in aerial photo of site).
- Water content in vadose zone monitored biweekly during summer using neutron probe in eight access tubes located within riparian zone.
- Sapflow data (three to four days per tree) were collected on a biweekly basis during summers of 2003 and 2004 using heat-pulse velocity method.



Major Controls on Water Table Fluctuations

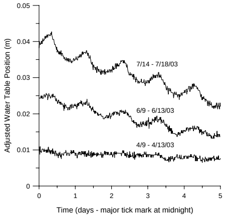
Temporal Variations in Plant Water Use

Plant water use varies within and between days in response to variations in global irradiance. Reduced global irradiance due to overcast skies on 8/19/04 at the LRS was accompanied by a decrease in plant water uptake, quantified here by the average sapflow velocity for a large (0.66 m DBH) cottonwood tree. The reduction in plant water uptake diminished the diurnal water table fluctuations (Well LWPH2) to an almost imperceptible level. Diurnal fluctuations in the water table only became discernable again after strong diurnal variation in plant water uptake was re-established after the precipitation event. The general decline in the water table is caused by plant water use as well as pumping in the underlying High Plains aquifer.



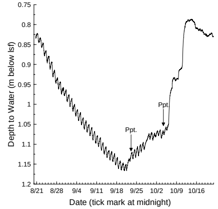
Major Controls on Fluctuations (cont.)

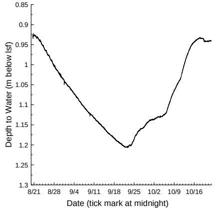
Temporal Variations in Plant Water Use

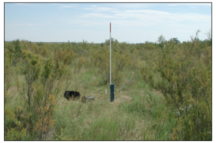


Plant water use also varies within and between seasons in response to variations in global irradiance, temperature, etc. Shown here are five-day water table records from the LRS (Well LWPH3) for three periods in 2003. Diurnal fluctuations are not discernable in April because major phreatophytes had not leafed out. The progressive increase in the amplitude of the water table variations was most likely produced by an increase in evapotranspirative demand coupled with a gradual depletion of the vadose-zone moisture and an increasing dependence on ground water. The general decline in the water table is caused by plant water use as well as pumping in the underlying High Plains aquifer.

Spatial Variations in Vegetation: The vitality of the phreatophyte vegetation often varies across the riparian zone and can result in spatial variations in ground-water consumption. The two figures below depict variations in water-table position for the same time period at two ARS wells (Ash 22 and Ash 32) less than 100 m apart. Although the salt cedar in the vicinity of both wells was last cut in the fall of 1996, the size and vitality of the vegetation is dramatically different. These visually apparent differences (see images below figures) are clearly accompanied by large differences in the amplitudes of the diurnal water-table fluctuations observed at the two wells.



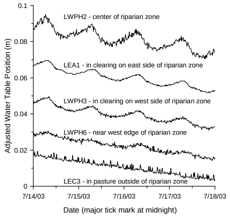




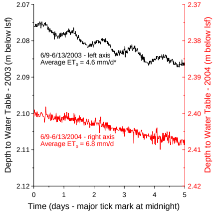
Major Controls on Fluctuations (cont.)

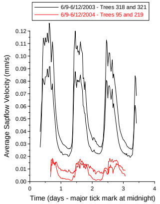
Spatial Variations in Vegetation

The characteristics of phreatophyte vegetation vary across the riparian zone, and ground-water consumption varies accordingly. Data collected at the LRS in mid-summer of 2003 demonstrate that the amplitudes of the diurnal water-table fluctuations clearly depend on vegetation density, type, and size. Well LWPH2 is in an area with a relatively high density of mature cottonwood trees, whereas LWPH6 is in an area with a relatively high density of smaller trees and no cottonwoods. Well LEA1 is in an area of lower density vegetation but the existing cottonwoods are the largest and oldest in the LRS. Well LWPH3 is in a clearing on the west side of the river channel that is surrounded by a mix of mature cottonwoods and smaller trees.



Temporal Variations in Hydrologic Conditions: Data from the LRS reveal the importance of past hydrologic conditions experienced by the riparian-zone vegetation. Show below is the depth to water at well LWPH3 for the same five-day interval in 2003 and 2004. Diurnal fluctuation are imperceptible in the water-level data from June 2004, despite the nearly 50% greater reference ET. The most likely explanation for the absence of fluctuations in 2004 is that the water table (0.32 m deeper than in June 2003) was out of reach of the vegetation. This explanation is supported by sapflow data collected during these two periods from cottonwoods of similar size and apparent vitality. Trees were undergoing stress in June 2004 as indicated by premature leaf fall and water contents near the permanent wilting point throughout the vadose zone. The water table was at a historical low in June 2004, so the most likely explanation for the stress is that the phreatophytes had not had a previous opportunity to develop a root network to extract water from that depth.





Conclusions

Diurnal water-table fluctuations are commonly observed in wells screened across the water table in vegetated riparian zones. Field data presented here demonstrate that these fluctuations are often a product of variations in plant water use. Diurnal water-table fluctuations can therefore be used as a diagnostic indicator of ground-water consumption by phreatophytes at many sites. These fluctuations can provide valuable information about plant water use at a scale that is intermediate between that of individual trees and that of a stand or reach. The use of water-table fluctuations as such an indicator has largely been ignored in the ecohydrology literature, where depth to the water table has been the primary hydrogeologic quantity of interest.