The Drought Cycle and Groundwater Chemistry

Barton Springs segment of the Edwards Aquifer

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"Hydro-Ilogical" Cycle

RAIN → Apathy → DROUGHT

Panic → MORE DROUGHT → Concern
Central Texas drought cycles

Palmer drought severity index

Jan-70 Jan-80 Jan-90 Jan-00 Jan-10 Jan-20

Palmer Drought Severity Index

Wet

Drought
Central Texas drought cycles

![Graph showing the relationship between Barton Springs discharge and the Palmer Drought Severity Index over time from Jan-70 to Jan-20. The graph indicates periods of drought and wet conditions.]
During rainfall, recharge occurs through streambeds and as direct infiltration.
After rainfall, flow in streams continues to recharge the underlying aquifer through conduits.
The Barton Springs segment of the Edwards aquifer

- Contributing Zones
- Recharge Zone
- Artesian Zone

Map showing the Barton Springs segment with areas labeled:
- Barton Creek
- Williamson Creek
- Slaughter Creek
- Bear Creek
- Onion Creek
- Barton Springs
- Marbridge well
- Buda well
Hydrologic conditions: transition from drought to wet

[Graph showing discharge over time with labels for November 2008 to March 2010, indicating dry and wet periods.]
Nitrate concentrations in streams increased when the drought broke in Sept. 2009.
...and were high relative to measured streamflow.

**Bear Creek**

**Onion Creek**

*Flow rate*

[Graphs showing nitrate concentration vs. streamflow for Bear Creek and Onion Creek, with data points for 1993-2008 and 2008-2010.]
Nitrate concentrations in groundwater had contrasting responses to the break in the drought (Sept. 2009)
Barton Springs: Nitrate concentrations were higher relative to historical levels
Isotopes of nitrate

Nitrate in precipitation

Synthetic nitrate fertilizers

Nitrate from ammonium fertilizers

Soil nitrate

Nitrate from human and (or) animal waste

AQUIFER FLOW CONDITION
ROUTINE SAMPLING
DRY WET
STORM
BARTON CREEK
WILLIAMSON CREEK
SLAUGHTER CREEK
BEAR CREEK
ONION CREEK
BARTON SPRINGS
BUDA WELL
MARBRIDGE WELL

Denitrification
What’s changed?
Septic systems permitted by year

No. of septic systems permitted


Barton
Williamson
Slaughter
Bear
Onion

USGS
Irrigation volume permitted by year

- Barton
- Williamson
- Slaughter
- Bear
- Onion

Volume (gallons/day)
Load Estimator (LOADEST): A Program for Estimating Constituent Loads in Streams and Rivers

Welcome to the U.S. Geological Survey (USGS) Web page for the LOADEST software package. This page provides access to the LOADEST software and documentation. These items and additional features may be accessed using the navigational tabs at the top of the page.

LOADEST (LOADEST) is a Fortran program for estimating constituent loads in streams and rivers. Given a time series of streamflow, additional data variables, and constituent concentration, LOADEST assists the user in developing a regression model for the estimation of constituent load (calibration). Explanatory variables within the regression model include various functions of streamflow, decimal time, and additional user-specified data variables. The formulated regression model then is used to estimate loads over a user-specified time interval (estimation). Mean load estimates, standard errors, and 95 percent confidence intervals are developed on a monthly and/or seasonal basis.

The calibration and estimation procedures within LOADEST are based on three statistical estimation methods. The first two methods, Adjusted Maximum Likelihood Estimation (AMLE) and Maximum Likelihood Estimation (MLE), are appropriate when the calibration model errors (residuals) are normally distributed. Of the two, AMLE is the method of choice when the calibration data set (time series of streamflow, additional data variables, and concentration) contains censored data. The third method, Least Absolute Deviation (LAD), is an alternative to maximum likelihood estimation when the residuals are not normally distributed. LOADEST output includes diagnostic tests and warnings to assist the user in determining the appropriate estimation method and in interpreting the estimated loads.

The LOADEST software and related materials (data and documentation) are made available by the U.S. Geological Survey (USGS) to be used in the public interest and the advancement of science. You may, without any fee or cost, use, copy, modify, or distribute this software, and any derivative works thereof, and its supporting documentation, subject to the USGS software User's Rights Notice.
Cumulative N loading

- Organic N is being converted to nitrate in the aquifer
- Total N is being stored (conservatively?) in the aquifer
Implications of nitrification

- Organic nitrogen $\rightarrow$ $\text{NH}_4^+$ (ammonification)
- $\text{NH}_4^+ + 1.5 \text{O}_2 \rightarrow 2\text{H}^+ + 2\text{H}_2\text{O} + \text{NO}_2^-$
- $\text{NO}_2^- + 0.5 \text{O}_2 \rightarrow \text{NO}_3^-$
- For every mg of ammonia oxidized to nitrate, 4.18 mg of oxygen are consumed
- Nitrification lowers the pH
Infiltration and discharge to surface water

Partial ammonification and nitrification; recharge to groundwater

Continued ammonification and nitrification of organic nitrogen
This work was done in cooperation with:

- Texas Commission on Environmental Quality
- City of Austin
- City of Dripping Springs
- Hays County
- Lower Colorado River Authority
- Barton Springs/Edwards Aquifer Conservation District
Additional information available

- Real-time physical properties at Barton Springs (site 08155500): http://tx.usgs.gov/
- USGS Fact Sheet: http://pubs.usgs.gov/fs/2011/3035/