Comments on Arkansas Nutrient Reduction Strategy (ANRS)

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The stated goals of the ANRS are widely supported by the Ozark Society and a strong majority of Arkansans according to a recent survey by the Arkansas Nature Conservancy. Who is not to like reducing the nutrient concentrations in Arkansas watersheds, providing local benefits and helping to shrink the Gulf of Mexico Hypoxic Zone? And working closely with stakeholders, actually every citizen, to adoptively manage and aggressively implement relevant practices and programs to safeguard state and regional economic prosperity, environmental quality, and recreational opportunities for current and future generations. But there are competing economic and esthetic interests which can make regulation or voluntary actions messy or divisive.

The following philosophic and management steps are acknowledged as in need of improvement (Appendix p. 1-5):

1. Spend your limited amount of money wisely, where the benefits are maximized.
2. Use real science to back up decisions, rather than political pressure or favoritism.
3. Acknowledge that goal 1 & 2 are difficult to implement at this time due to previous sporadic sampling, limited databases, inadequate distribution of discharge gages, and need for technicians, hydrologists, and data management people to make effective use of current and future databases.
4. Use clear cost-benefit analysis, e.g. progress was achieved by a program or not.
5. The Tier system makes sense, but is unwieldy at this time.

All further OS comments will pertain to the Appendix.

At times the Appendix was difficult reading.

On the light side, on P. 12 we read "0.10≥p<0.20", a typo surely for $0.10 \le p < 0.20$, but this mishmash was repeated three times.

More substantial. The goal of monitoring and reducing nutrient loading was largely ditched at the onset by the choice of median as the prime tool. While partially stuck with this tool perhaps by lack of discharge locations there may have been enough sampling locations with discharge information to help guide the conclusions from using medians only. Maybe these studies were done but it didn't merit reporting in the Appendix. Or maybe using one statistical tool is the most cost efficient method right now, to be corrected in the future.

Simple numerical examples, and graphs, can be effective tools for understanding a messy procedure.

Observations on the use of medians, percentiles, etc.

1. The reason for using 75^{th} percentiles of site medians was not initially clear. On page 32, the widely variable site count, and the use of one point estimators for a median suggested the rationale: How are data sets of varying size analyzed and combined using medians or percentiles? Is there a possible biological comparison advantage to using the 75th percentile?

However, the use of median in a subgroup tends to **eliminate high concentrations** which then remain eliminated in the 75th percentile. For an example with real data consider nitrate on Mill Creek, a tributary of the Buffalo River. For four sets of 5 random samples having an overall median = 0.666 mg/L, the 75th percentile of the 4 medians however is 0.722. Not much change, in fact it is the 58th percentile of the original sample set. However, reversing order, the median of the 75th percentiles = 0.927 which is the 80th percentile of the original set. Sequential data sifting and culling should be justifiable.

2. The **geomean, mean and flow weighted mean are all some percentile of a data set**, but not necessarily related to the median. Example: For TP upstream from C&H on Big Creek: geomean = 57th percentile, mean = 76th percentile and flow weighted mean = 91th percentile. Perhaps these percentiles are characteristics of a watershed and might be useful.

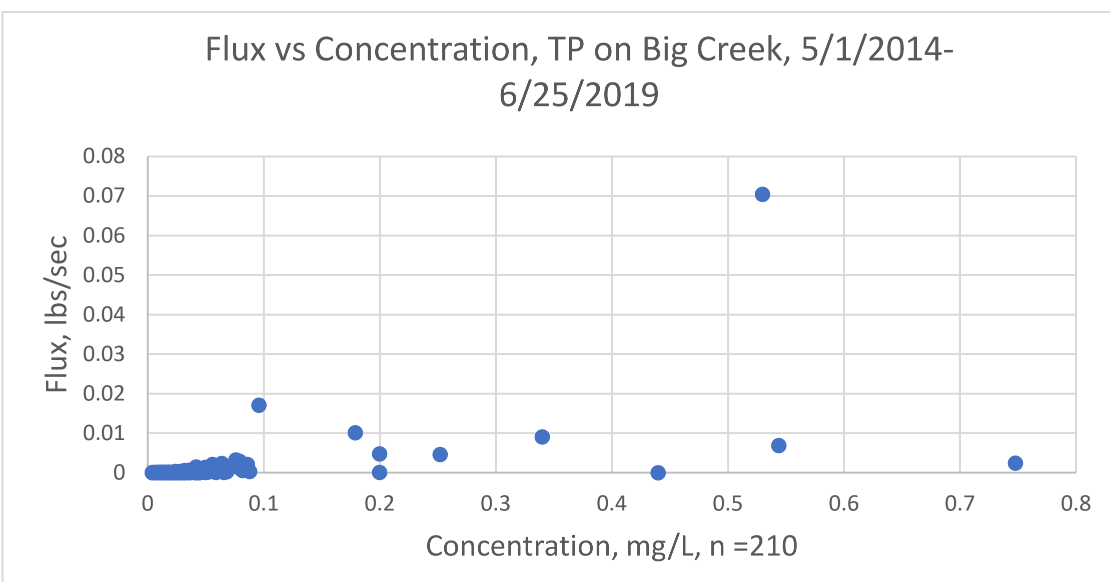
3. **Confidence intervals** are relatively large for small data sets as employed in this study. Example. For ordered data {Y_1, Y_2, … Y_8} as might occur in yearly sampling by DEQ, the 95th confidence interval for the median is the interval from Y_1 to Y_7. The determination of significant differences is thus difficult.

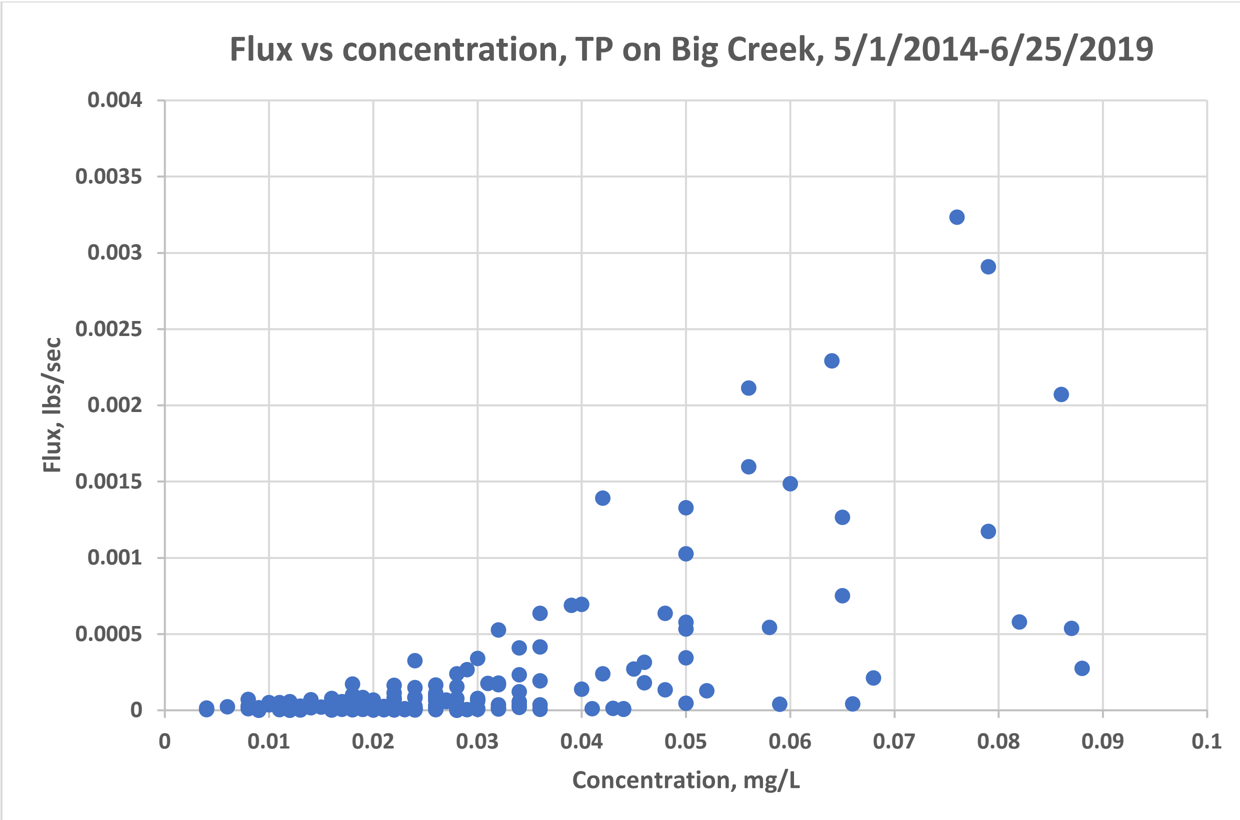
4. The **median is the worst estimator** of TP load, **outliers matter**. Using data collected by BCRET on Big Creek from 2014-2019, n = 210. Among central tenancies, **the flow weighted mean is the only direct measure of load**. (The geomean is always less than or equal to the mean).

TP (mg/L)	Median	Geomean	Mean	Flow Weighted Mean
Below C&H	0.024	0.028	0.044	0.123 (0.070*)
Above C&H	0.024	0.026	0.037	0.064 (0.056*)

* One "outlier" removed.

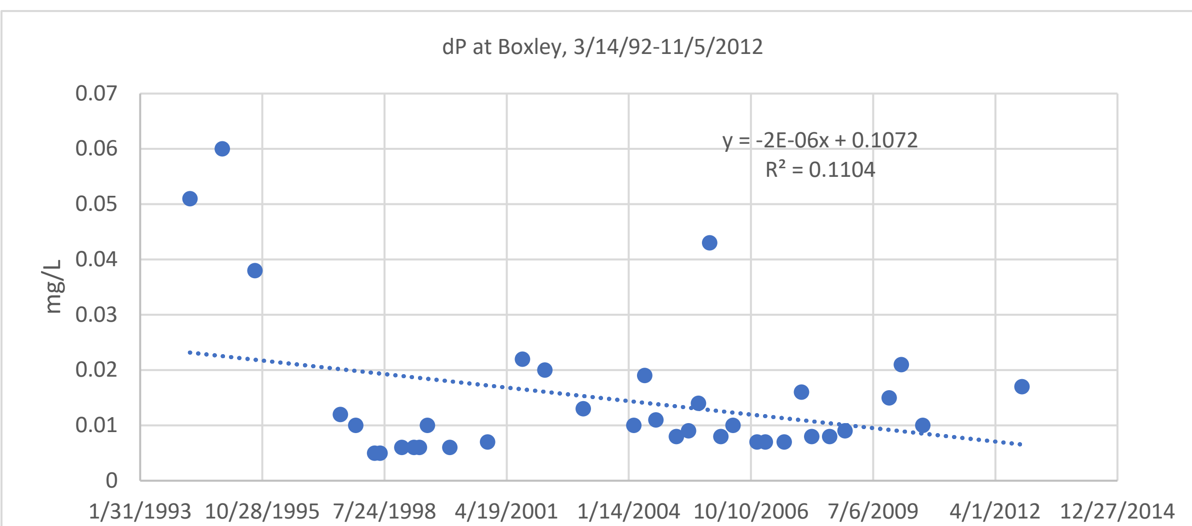
Flux, instantaneous concentration times discharge, is correlated to concentration, of course.

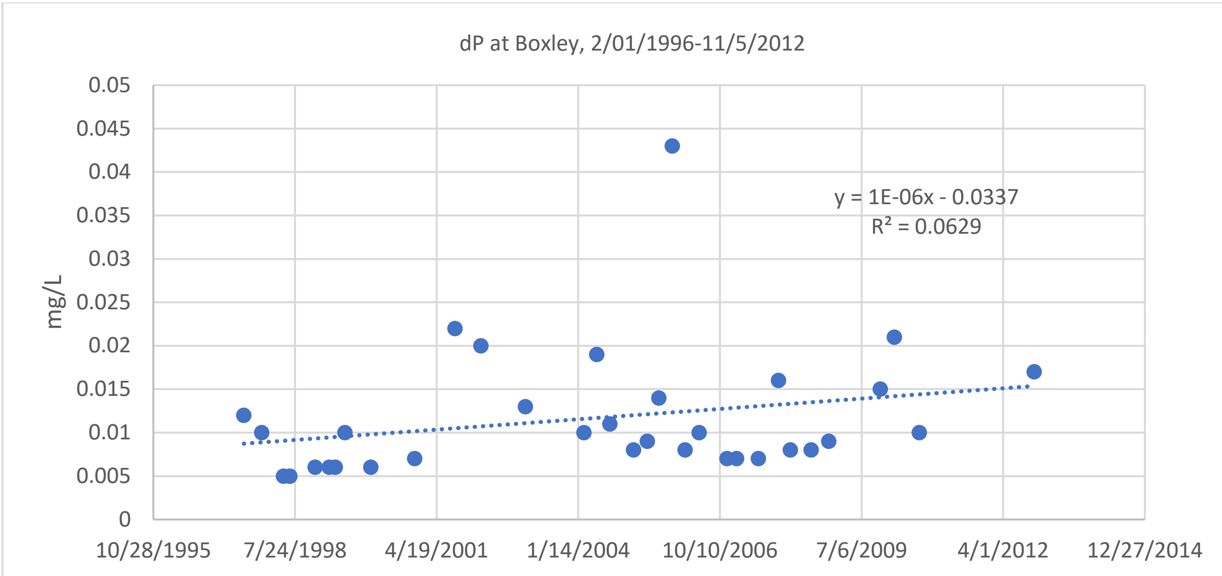




A closer look at the median - the flux in the median range, 0.024± is essentially irrelevant for estimating load! The 90+ percentile is a much more likely correct region but small data sets makes this impossible to use accurately. The median seems **to be unfixable** as a tool for estimating load.

5. The Appendix seems to **not** have fallen into the starting point trap. **Trends depend on starting points and amount of data:** Is dP increasing or decreasing at Boxley?





6. Forbidden algebraic manipulations

- **By definition dP ≤ TP,** typically in water samples dP is considerably less. Roundoff errors, or samples near the limits of detection might include some data with dP > TP but otherwise there are problems with the non-coinciding data collection dates when dP > TP occurs. At least one published paper on the BR watershed used data with dP > TP.

- Although for any one sample, nitrate + TKN = TN, for data sets like the ADEQ collection, typically

  average {nitrate} + average {TKN} ≠ average {TN} ,

  unless the dates of collection are identical, which is rarely the case. Example from Mill Creek:

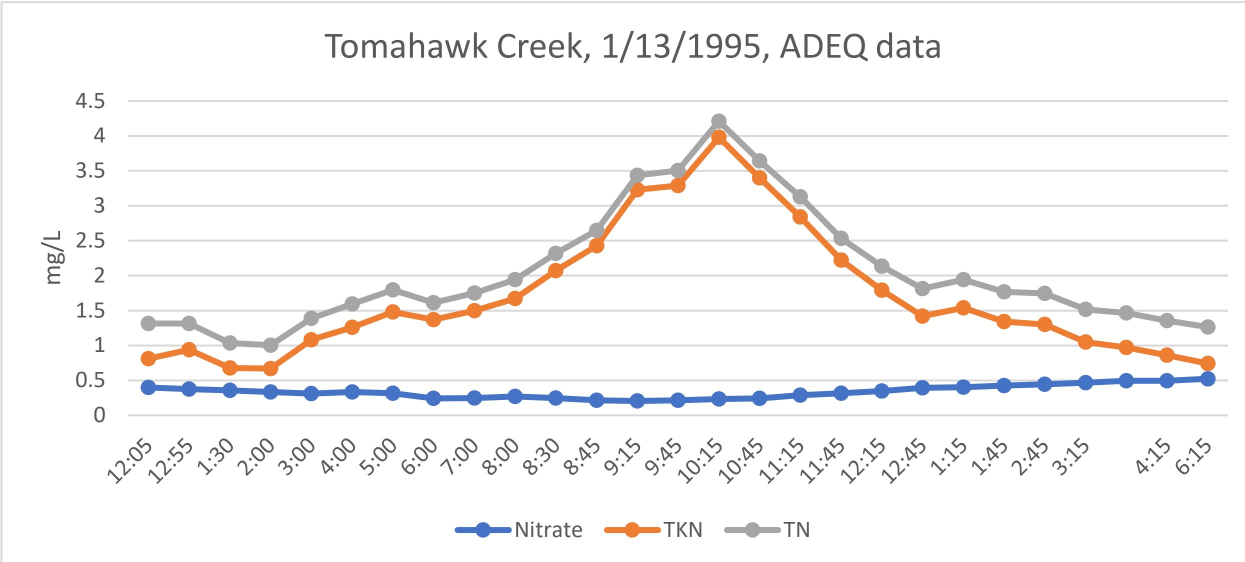
  mean {nitrate} + mean{TKN} = 0.64 + 0.19 = 0.83 ≠ 0.97 = mean {TN}

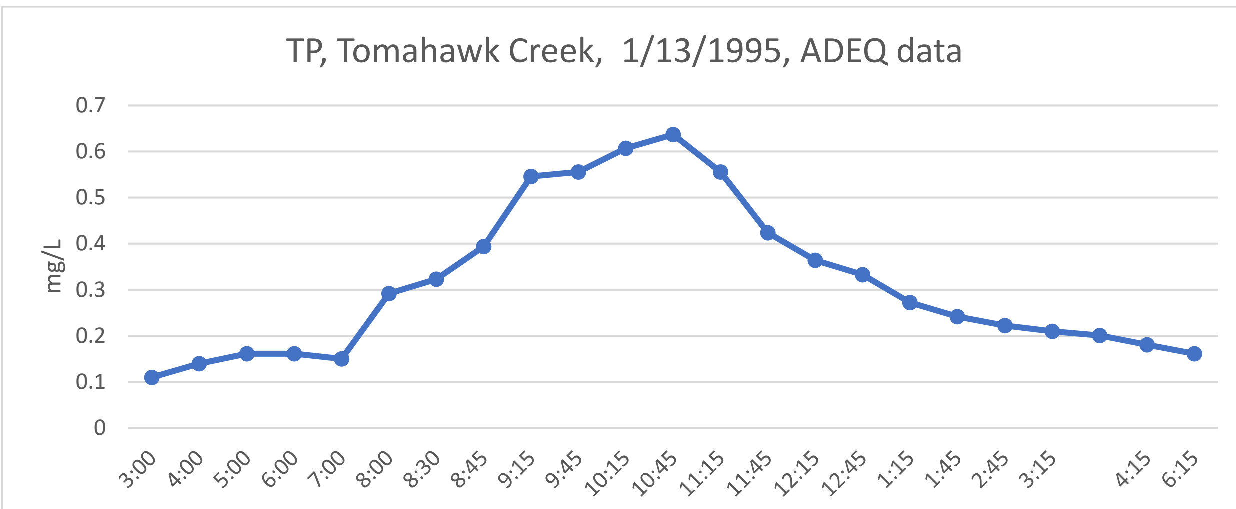
- Typically, **median $\{a_j\}$ + median$\{b_j\}$ ≠ median $\{a_j + b_j\}$,**

  even if the collection dates are the same. This is the case for percentiles as well.

- **Geomean $\{a_j \times b_j\}$ = geomean $\{a_j\}$ x geomean $\{b_j\}$ if the data sets are the same size**, but almost no other algebraic manipulation of geomeans works.

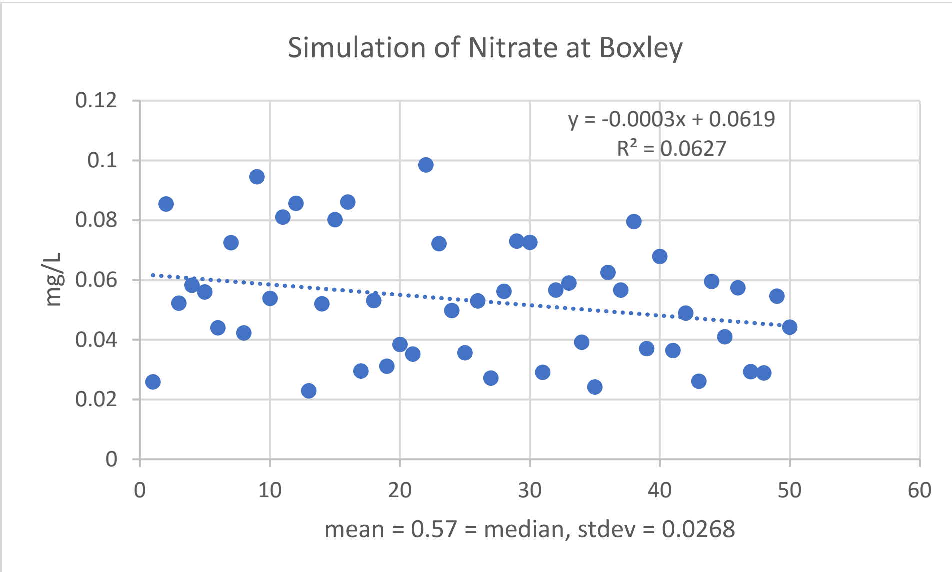
7. **It is unusual for ADEQ of other collection agencies to record a spill or flood event and record data as it unfolds - it requires many samples, it costs.** The USGS attempts models to estimate storm flow TP when actual data is missing. It might work.



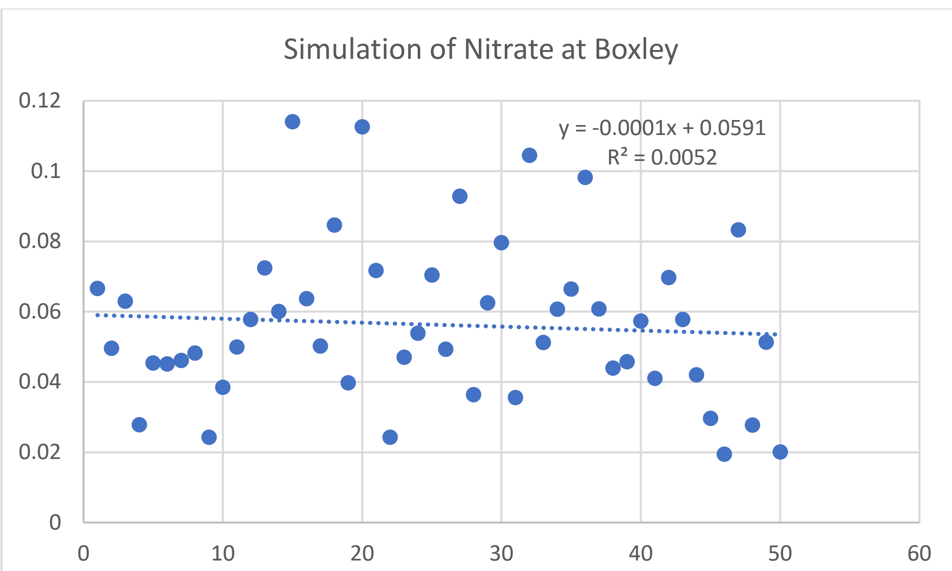


The surge (plumes) in TKN and TP suggests a waste pond leak or overland flow of recent waste. (The Buffalo River flood surge at St. Joe on 1/13/1995 was over 50,000 cfs, 26 feet!) These are very high numbers for tributaries of the Buffalo River. Nitrate is typically about 60% of TN, rather than almost none as in this case, and the TP values are 30 times normal at the peak, so there was some exceptional source. Given the very high TP levels and probable high flow rates, the load was likely very high, but the use of only medians only would the event. Tomahawk Creek and Mill Creek been historical trouble spots on the Buffalo River.

8. Seeing trends when there are none.



Hydrologists often assume that data is lognormal, i.e. the random variable LN(x) is normally distributed. If so, as in this SIMULATION, then mean = median, but not vice-versa necessarily. There is **no trend** since the listing of data on the x axis is entirely random as it comes out of the computer, despite the extraneous curve fit and R^2 computation. Humans, especially scientists, are trained to **identify trends that are not random**. But these simulations look like typical data with deceptive “trends”.



9. Best Management Practices

Of course, it is better to retain excess P in the field edges and ponds than allowing it to enter water courses, except that recent research shows that these areas can become sources of legacy P when application rates exceed agronomic needs. The benefits of BMP require a long term study.