Monitoring the potential for subsurface delivery of phosphorus to streams in the Cannonsville Reservoir watershed

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As the title suggests, we were interested in finding out if P could be reaching surface waters via the groundwater.

Most of my talk will be about the process of our investigations, with some slides near the end of our results & conclusions to date. Lab data is still trickling in…

Background

- Cannonsville Res. tends to be eutrophic, with excess phosphorus.
- **D**elaware **C**ounty **A**ction **P**lan (DCAP) seeks to understand P sources & reduce excessive releases.
- Previous modeling by SWAT (DCAP/Cornell) and GWLF (DEP) indicate up to 33% of dissolved P entering reservoir may be associated with *groundwater* (!) [20-30 μg/L = SWAT calibration values]

Excess P from a variety of sources, originating above ground.

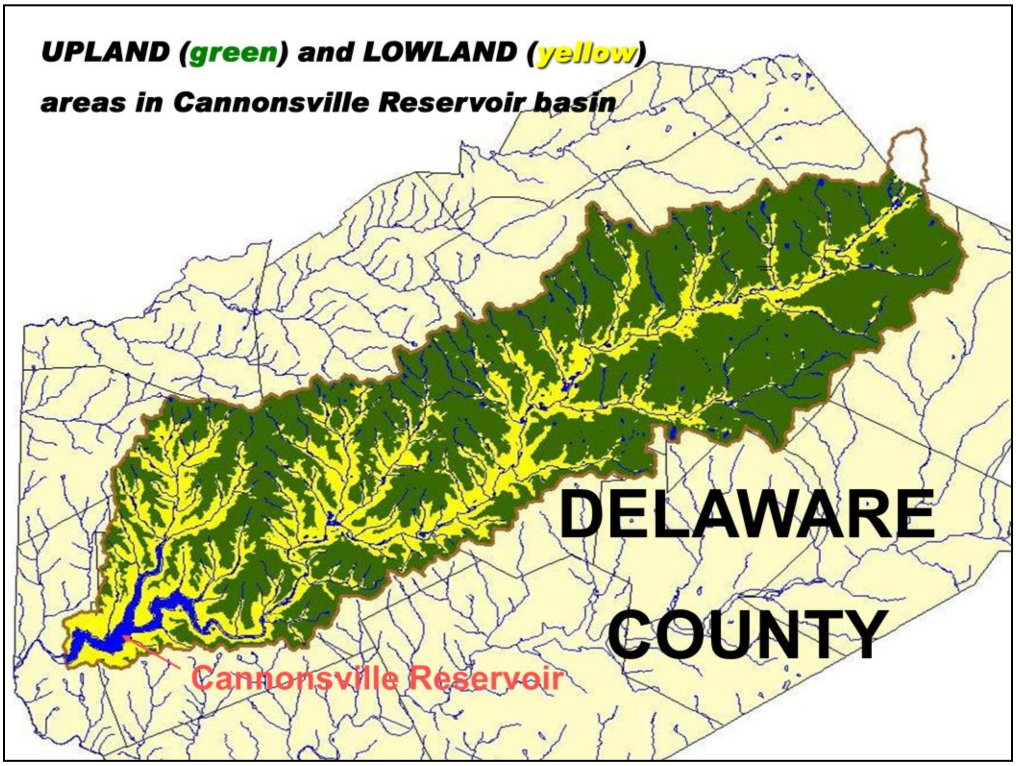
DCAP directs county resources to fill gaps and stop unnecessary leakage of P. CSSG considers the role of research.

Tolsen and Shoemaker (2005) estimated 20-30 ug/L, with higher values occurring in those subbasins having more livestock operations, and less in forested watersheds. These values are roughly in line with DEP's research with GWLF model.

Another mechanism suggested that low-P groundwater could be releasing P from sediments in streams. We did not study this possibility but rather looked at P in GW *per se*.

Background (continued)

- Groundwater sampling is needed to verify, quantify, and determine if inputs appear source-related.
- SDWA - 2002 grant was obtained through NYS DEC.



Starting with the idea of looking at source areas and non-source (background) areas, we also wanted to separate our sites based on upland vs. lowland areas.

This is actually a map of the break between mesic and frigid soil temperature regimes in the Cannonsville basin. While it exaggerates the amount of what we considered “lowlands”, it gives a pretty good idea of the distribution of upland glacial till and lowland alluvial soils.

Streams originate in uplands where perched water tables and interflow are common at shallow depths. This is in contrast to the lowlands where more permeable subsoils do not favor perched water tables, but rather we’d be sampling the near-surface of the water table aquifers in valleys.

Approach

- Reconnaissance-level site selection
- Represent contrasting yet typical land uses
- Use reference / “background” samples for comparison
- Stratify by upland (glacial till) & lowland (fluvial-alluvial)
- Choose sites relatively close to streams
- Need high analytical precision for dissolved P

For reference or “background” P levels we were looking for one or more relatively pristine sites that had little or no history of added nutrients.

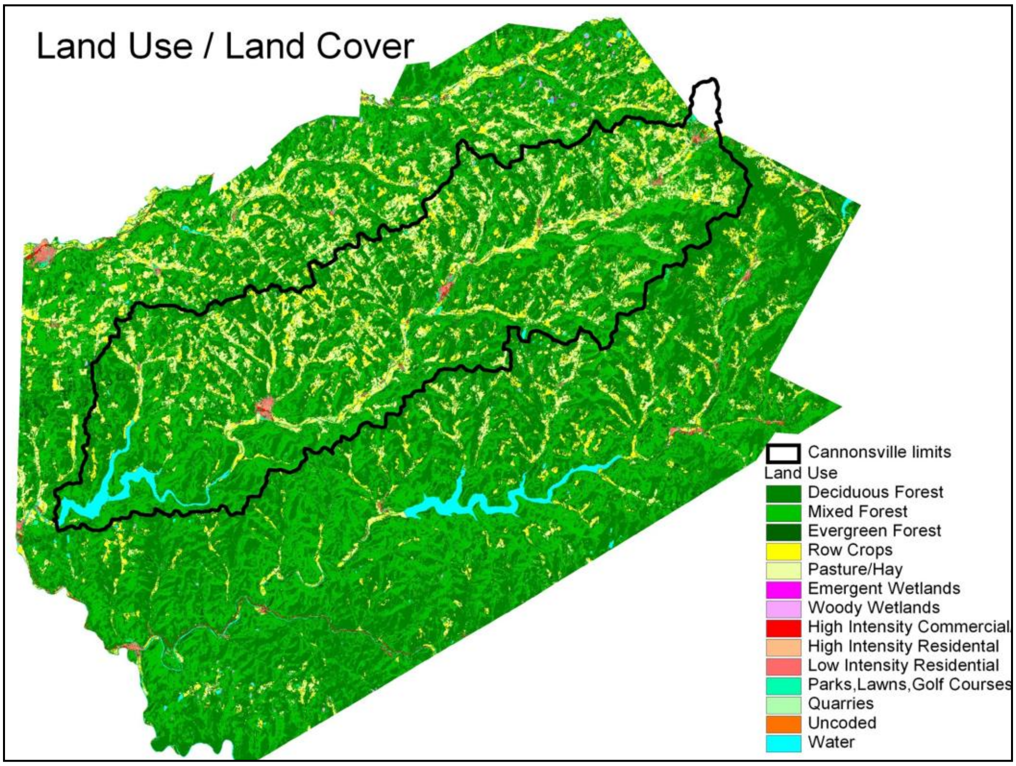
To our knowledge, this research was the first systematic GW sampling for TDP in the watershed that we are aware of; at reconnaissance-level only.

Land Use	Phosphorus Sources	*Expected P Level*
Mature forest	Soil parent material weathering	LOWEST
Residential area, sanitary sewers	Lawns, Leakey sewerage	LOW
Former farm fields and farmstead	High-P fields, Barnyards	LOW - MODERATE (variable)
Active farm fields and farmstead	High P fields and ongoing Manure spreading	MODERATE-HIGH (variable)
Residential area, septic systems	Septic systems, Lawns	HIGH

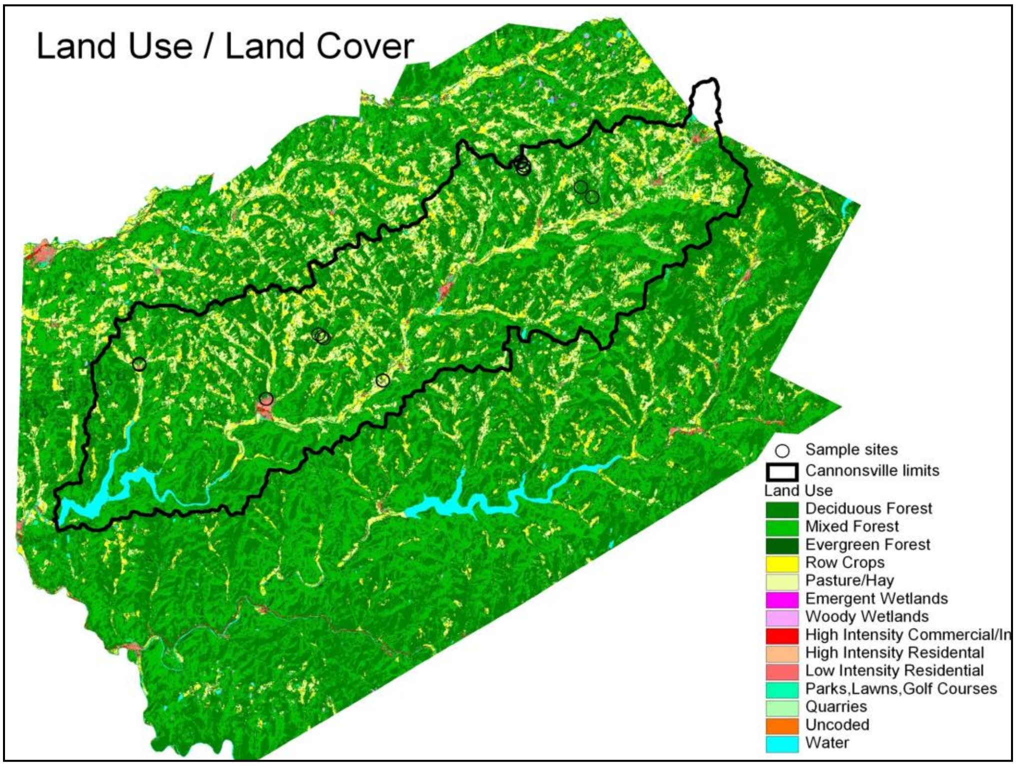
This table shows what we'd expect, from prior research and knowledge of sources.

We didn't find a lowland mature forest that we could sample.

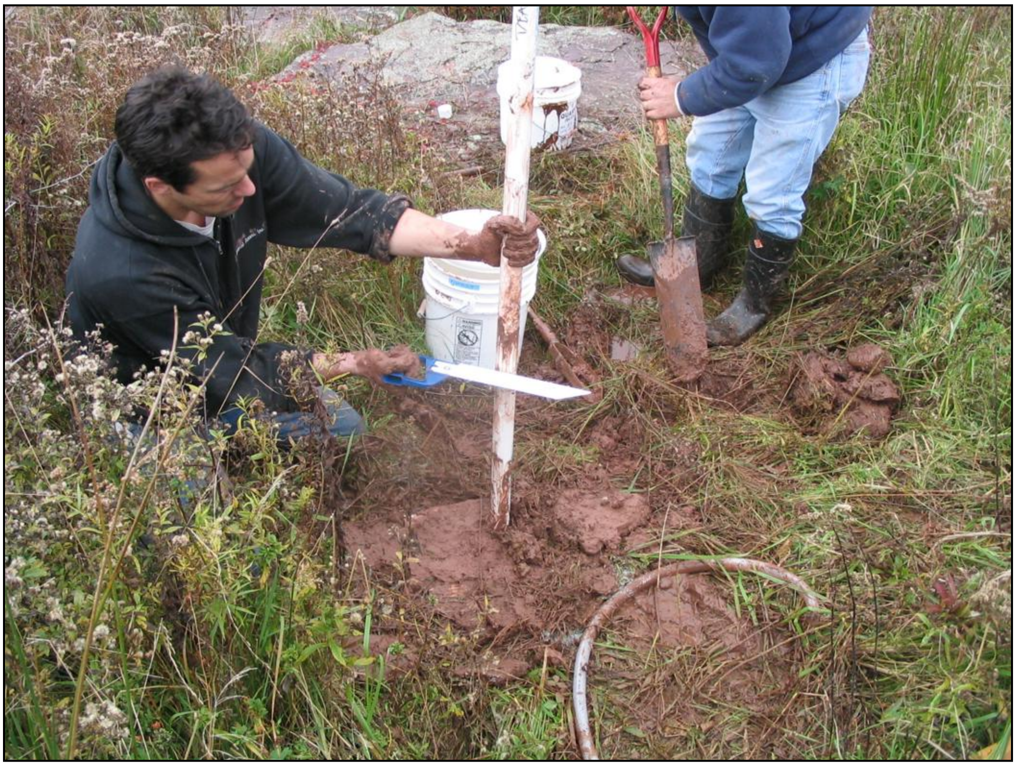
Residential areas usually not heavily fertilized relative to other urban areas (no "Chem-lawn" business).



Forested areas in shades of green, agriculture in yellow, developed areas in red.

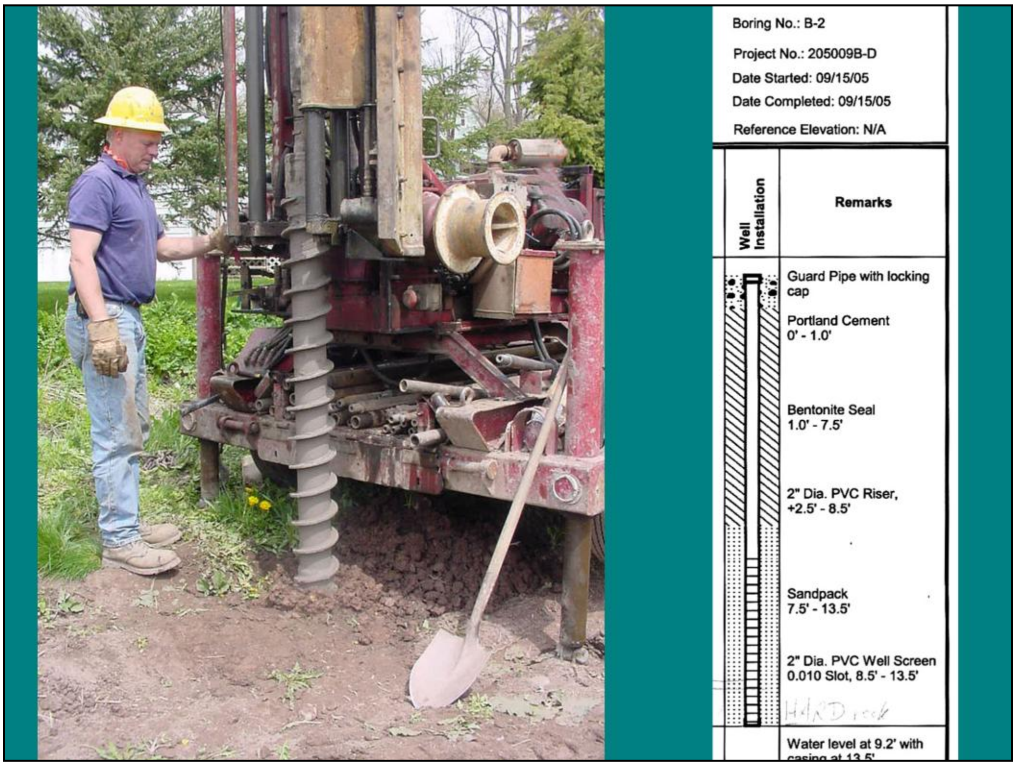


Land use + sample sites. Control area here, upland farm, former barnyard, residential development with septics, residential with municipal sewers in the northern section of the metropolis of Walton.



Upland glacial till soils, with shallow depth to fragipan or dense substratum, required wells only one meter or so deep, which allowed installation by hand tools. These first wells were installed in the fall of 2004, and consequently we have the most data from them.

(This slide shows Dean Hively at work; he collaborated with us on the project as a post-doc at Cornell, but has since moved on to USDA in Beltsville.)

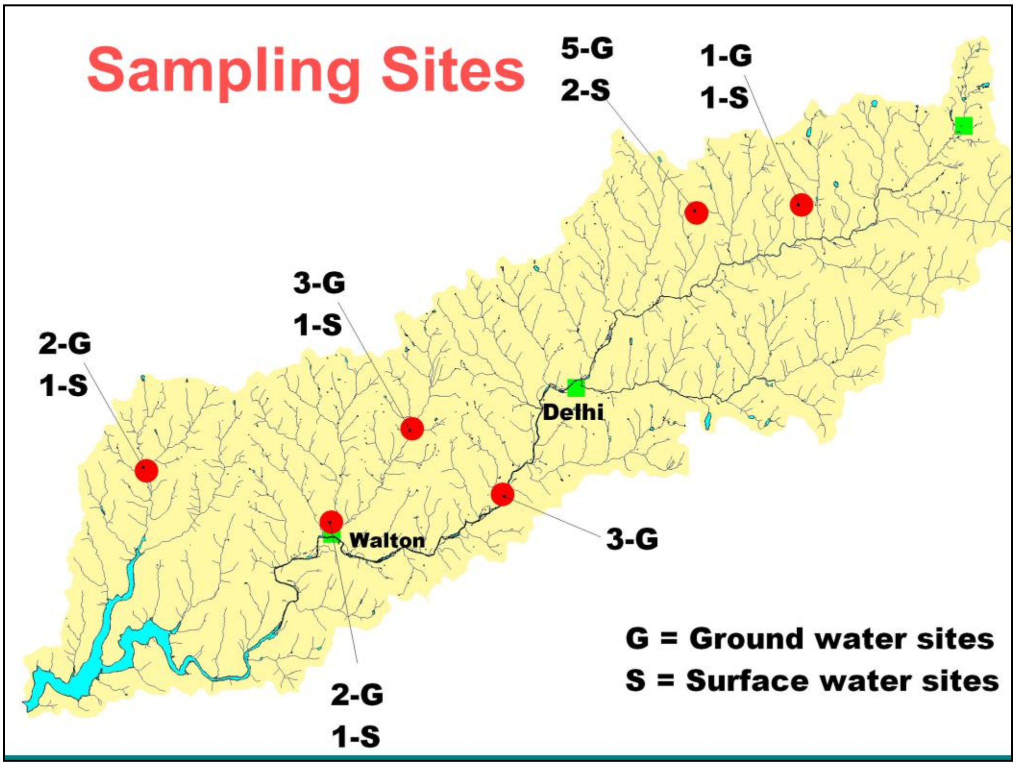


Lowland sites typically required wells 10-20 ft. (3 to 6 meters) deep and had so much gravel and cobbles in the soil that hand tools didn't work, so we hired professional well installers. The last of these wells were installed last September, so we have a minimum of one year's data from each sampling site.

Note standard well installation detail on right. Besides the usual components of sand, bentonite seal and backfill, we typically used a "nested" design -- one well would have a 5-foot well screen that straddled the water table for "shallow groundwater" samples, and an adjacent, slightly deeper well with a 3-foot screened interval. This arrangement allowed us to look for vertical stratification of dissolved components.

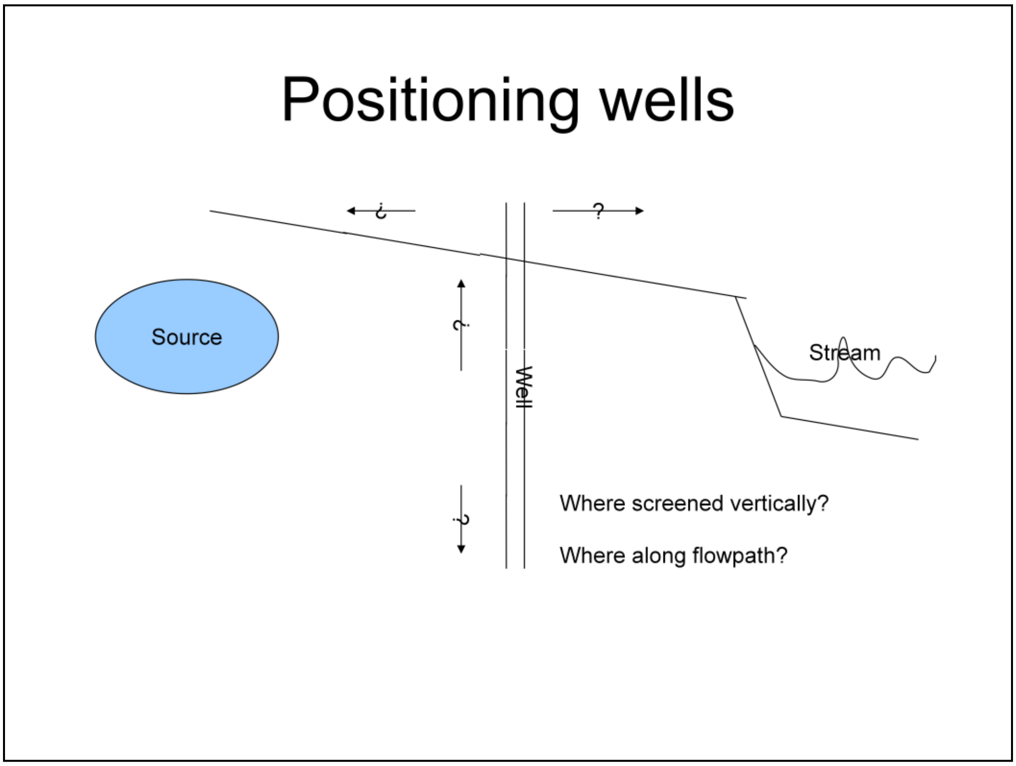
Our GW sites also had a nearby stream for sampling surface water, since it is the surface water that would likely be affected by the entering groundwater.

This is one of our sites in the Village of Walton. Since the flood in late June, the stream doesn’t look quite the same. But the wells survived and we did get one round of post-flood samples.



This slide shows the distribution of our sampling sites in the watershed. Note that each groundwater site has a companion surface water sampling site as well, with the exception of one site where surface water was considered non-representative. We also sampled nearby springs in two locations, which we considered groundwater. [Give examples]. Some sites had springs we could sample, some did not; so the number of groundwater and surface water samples per site varied between sites.

Note R-farm and Shaw Rd. include 2 sites extensively sampled by DEC for TDP in surface waters.



Very few P sources are right up to a streambank, so we always have to decide where between the source and stream to put our wells. *We strive for close to stream, but gave priority to being near to the source.*

Very few P sources will saturate the entire vertical water column. A septic system plume can be narrowly confined. *We bracket the levels with pairs of wells screened at different depths, when possible.*

Besides a cross-section concern, most P sources other than active farm fields are nonuniform laterally. At least two wells per site.

Plan view of typical layout of wells in relation to potential sources and surface water. Because the catchment area differs between the stream and the upgradient wells, surface water samples were used to help set the general context of results from the wells. In some cases, like this one in Trout Creek, we were constrained as to where we could locate our wells. They were often placed closer to the potential P source than to the companion stream.

Sampling

- Fall, 2004 — Summer, 2006 (n=6 to 12)
- **Dissolved phosphorus** (0.6 µg/L)
- Nitrate-N
- Major Cations and Anions
- In-field: pH, temp., conductivity/Spec. Cond.

- (USGS-suite of wastewater parameters)

1) Wells were installed as sites were agreed upon and access was approved; thus some sites were available for sampling over a longer period than others. Full year of coverage for each site, in case of seasonal variations.

2) Dissolved-P is a biologically active form, which can be closely associated with algae growth. We found Upstate Freshwater Institute lab provided both very precise analyses with high reproducibility.

3) Nitrate-N helps indicate whether a pollutant source exists that might affect GW.

4) Major cations and anions help show fundamental differences in GW sources, or mixing.

5) In-field tests relied on a YSI hand-held meter.

6) Four wells that seemed affected by wastewater were selected for USGS sampling.

Sample handling

- Objective: reliably detect low single digits of TDP
- Elements: very clean washwater, gloves, separate hoses, obsessive lab apparatus washing, field and lab blanks analyzed each time
- Results: reliable down to about 2-4 ug/L, based on blanks consistently below 2 ug/L

We expected to find TDP concentrations in the 1-100 ug/L range. The low end is background, from DEC stream baseflow sampling in a mostly forested “control” site for a farm study.

To get close to 1 ug/L we have to be very clean to keep ourselves from contaminating, and to prevent cross-sample contamination.

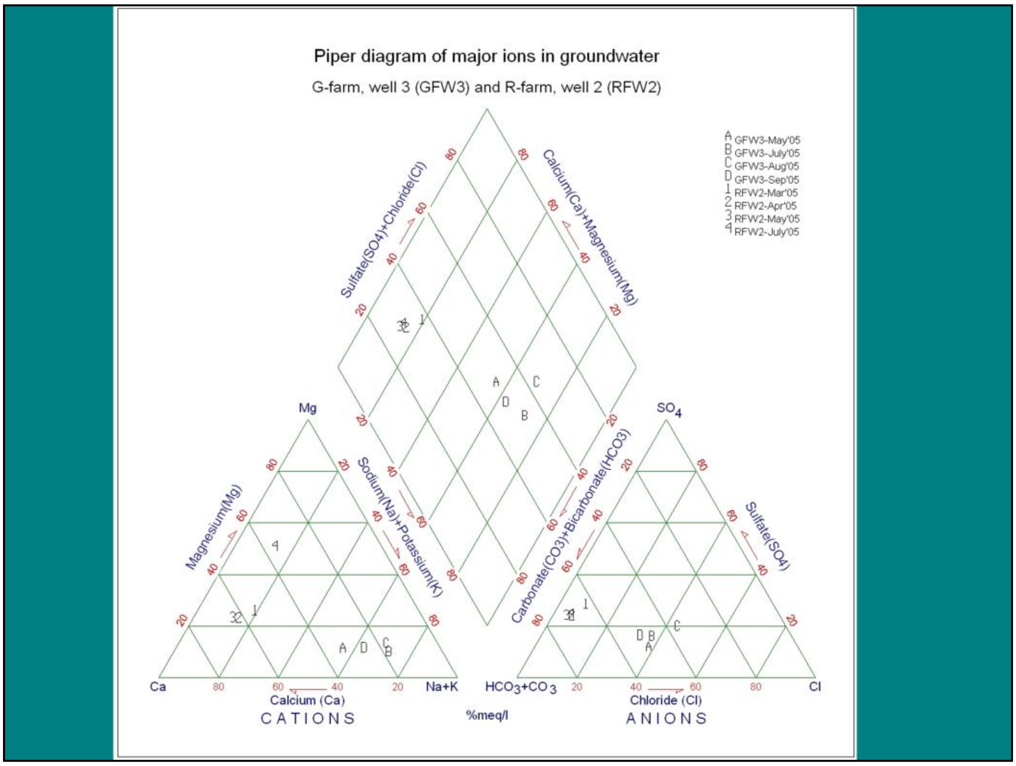
The lab can detect down to 0.6 ug/L. Our “lab blanks” (deionized water not going through any apparatus) come out under 2 ug/L, and our “field blanks” are essentially the same as the lab blanks. So our noise floor was around 2 ug/L, as desired.

Sample counts

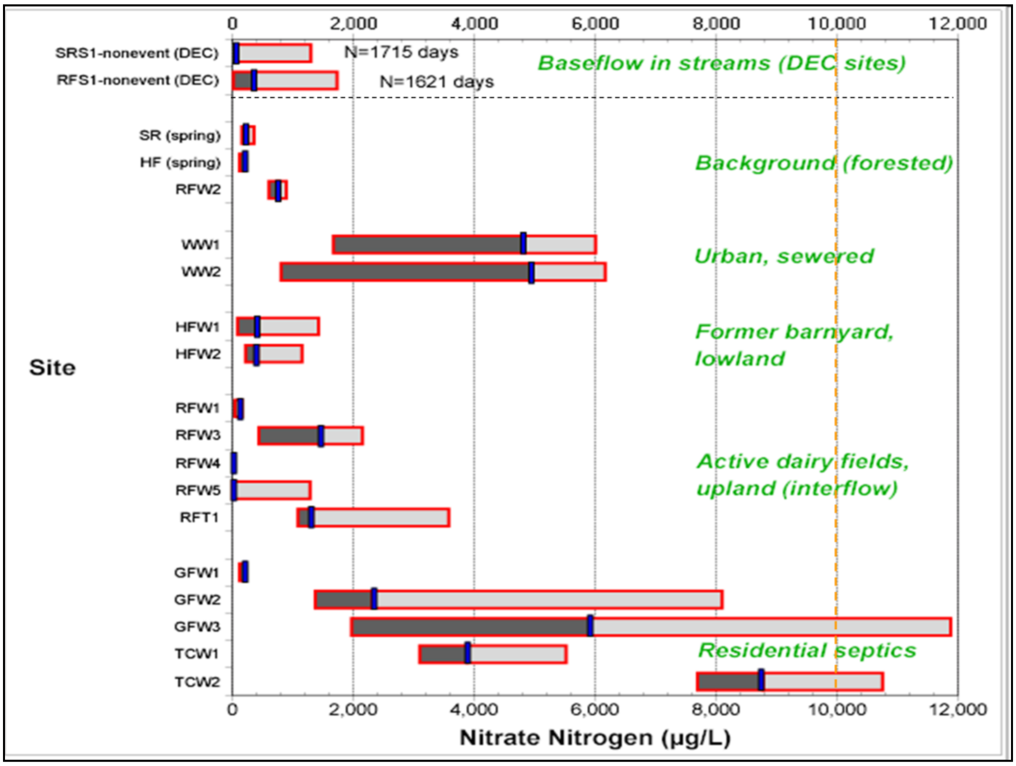
- 182 samples, 14 parameters / sample, 39 blanks
- 1 to 2 month sampling interval
- Minimum 1 year's data per sample point

Last point: Minimum 1 year's data collected in case there was any seasonal variability.

Results:



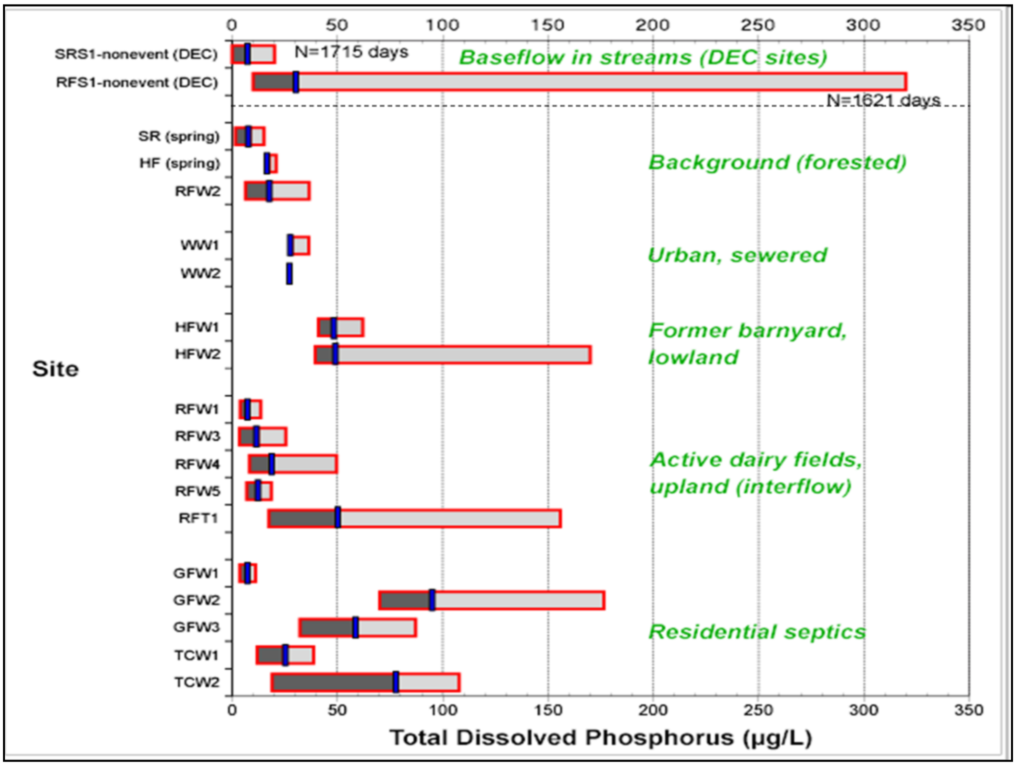
Fundamental groundwater chemistry, as shown in the Piper diagram of some samples from 2005, indicated that there were differences in major ion balances between upland and lowland sites.



The sites are grouped according to the categories of strength of P-sources, from lowest to highest, that we anticipated. Sites are on vertical axis; please focus attention on median values, = blue stripes.

Again, Nitrate used as an indicator that well is affected by some nutrient source, likely to include TDP.

Upper two bars represent the “Paired watershed study” by DEC represents years of accumulated stream data.



"Background" TDP in forest springs (and headwater streams in these areas) is 5-15 ug/L.

The "Urban, sewered" site showed slightly higher values that we had expected, with medians around 25 ug/L.

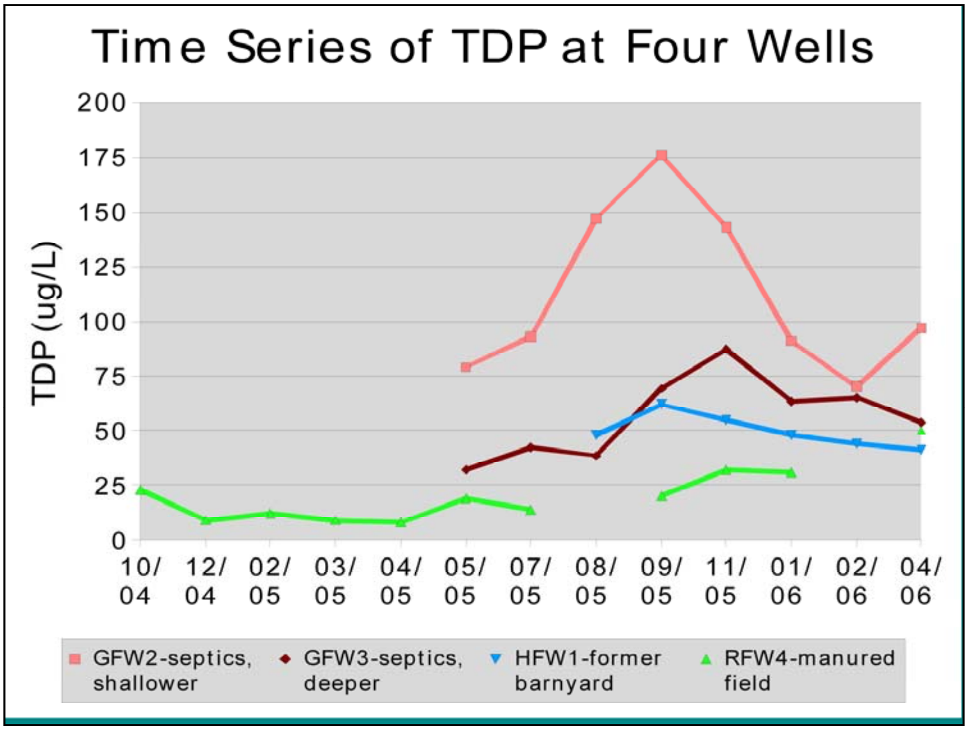
The Former Barnyard area (which had high P in soil) showed high TDP. This represents "slow leakage" of P, even a few decades after any animals have been on the site.

The relatively well-managed, active dairy farm in upland soils had some of the lowest median TDP values, not much above background levels. (We have the most data points and samples from this farm, representing 2 year's worth of samples.) The tile drain below a pasture was a notable exception, for reasons we cannot explain but may have to do with not having any bentonite seal allowing more surface water.

The wells downgradient from clusters of residential septic systems produced the greatest TDP values. Judging by the high nitrate values as well, it appears likely that wastewater is the major source; USGS samples due later this month should help answer this question.

Large variation between concentrations of P and Nitrate at paired wells downgradient from septic sources, which implies that a large number of wells might be needed to characterize GW loadings.

Overall, the medians do tend to fall within or above the 20 to 30 ug/L range predicted by Tolson & Shoemaker.



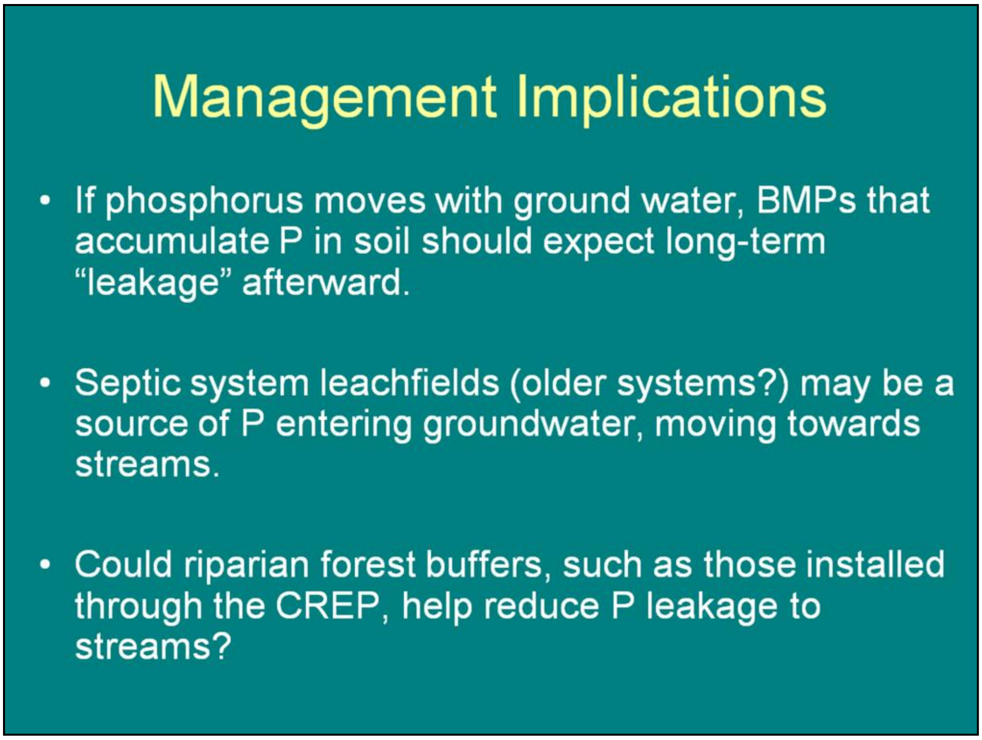
It may not be completely proper to use line plots to connect results taken so far apart in time, but it shows better than bar charts that **there does seem to be some seasonal effect** such that the highest values occur in the late summer to fall months and minima occurring in mid-winter to early spring.

The last rounds of sampling results may help clarify this picture.

Conclusions

- TDP in shallow groundwater appears to corroborate calibrated 3000-5000 kg/yr TDP loads in basin models.
- TDP appears to vary by Land Use. Higher levels near clustered septic systems & high-P farm fields, lower levels in forested areas with no concentrated P sources.
- Apparent seasonal variations imply that >1 year of ~monthly sampling needed to characterize TDP in groundwater.
- TDP will continue leaching from "hot spots" for years to come, and likely enter surface waters due to close proximity.

Shallow groundwater below contributing sources is potentially a major source of P-dissolved entering reservoirs.



Agricultural BMPs that accumulate nutrients (could include any practice that concentrates nutrients, such as wastewater filter strips, barnyard runoff management, animal trails & laneways, designated temporary manure pile areas, heavy use area protection, watering sites near streams) will produce leakage areas of the future.

The "final barrier" approach of stream buffer strips seems like a useful BMP.


Questions?
HFW1
GFW1
HFS1
GFW2
TCW1 #2
July 2006
WFB