Delaware County Action Plan for Phosphorus Reduction SDWA 2002: Monitoring of Subsurface Phosphorus Delivery to Streams

Final Technical Report

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1. Introduction

1.1 Background and Purpose

If the Delaware County Action Plan for phosphorus reduction (DCAP) is to meet its goal to reduce phosphorus delivery to the Cannonsville Reservoir by several thousand kilograms per year, all mechanisms that can potentially deliver P to streams must be considered (Delaware County Board of Supervisors, 2002). In the Cannonsville Reservoir basin, the presence of shallow soils overlying a fragipan, combined with limited field evidence and modeling calculations, suggest a high potential for phosphorus to be conveyed by sub-surface drainage to streams, and thence to the reservoir.

Costly options are being evaluated by Delaware County in its Manure Management plan, which will change farm manure application rates, patterns and timing, and will likely require the purchase of numerous manure storage structures. Analogously, there are important implications for the location of septic systems across the rural landscape. Despite their expense, it appears that the effect of these practices may not be measurable in water quality for years to come due to the slow "leakage" of accumulated P through groundwater flow to streams.

In tandem with improved phosphorus understanding in soils, there has been progress in calibration of terrestrial non-point source water quality models to the Cannonsville Basin and small research watersheds within it. Calibrating these models has yielded coefficients that indicate that up to one third of dissolved phosphorus arriving at the reservoir might be attributed to groundwater. This amounts to 3000 - 5000 kilograms per year of dissolved phosphorus (NYC DEP, 2001; Tolson and Shoemaker, 2004).

Various mechanisms have been suggested by which groundwater flow could be associated with elevated P in streams. These include short-circuiting of surface-applied sources (manure) through macro-pore flow into interflow zones, matrix leakage of mineralized P through soil zones that are P-saturated, and the possibility that while groundwater itself may contain insignificant quantities, P is released into surface waters as groundwater flows upward through P-enriched sediments in streambeds.

Prior to this project, groundwater has not been systematically monitored for P in the Cannonsville Reservoir basin. This project measured groundwater phosphorus concentrations between different land uses and surface water bodies to determine if model-estimated groundwater P-loadings to streams, which have been estimated to be significant, can be substantiated.

The Tolson and Shoemaker (2004) work estimated average phosphorus concentrations in groundwater discharging to streams to be on the order of 20 - 30 micrograms per liter, higher in subbasins having substantial livestock populations and lower in subbasins having mostly forest land.

1.2 Project Calendar

The project originated through discussions within DCAP in 2002, was funded in 2003, began active sampling in 2004, and concluded in late 2006 (Table 1).

Table 1: Project Chronology

Stage	**Period**
Proposal	2002
Contract development	early 2003 to mid 2004
Planning and design; initial candidate sites	early 2004 to fall 2004
Active sampling	November 2004 - July 2006
Last sites added	Fall 2005
Closure	August 2006 - December 2006

1.3 Related Projects

The tail end of NYS WRI's role in the DCAP R Farm project (NYS WRI, 2005c) dovetailed with the beginning of the project covered by this report.

A project managed by Tammo Steenhuis of Cornell Biological and Environmental Engineering and implemented by Francisco Flores-Lopez installed wells and sampled shallow groundwater at the "lowland farm" near the hamlet of Trout Creek. This DCAP project and that project have exchanged databases, and also tested for comparability of data. Excerpts of data from that and this project will be included in subsequent publications, after publication of Flores-Lopez' PhD thesis or journal articles.

1.4 Acronyms and Abbreviations

This report contains many acronyms and abbreviations. Table 2 summarizes their meanings.

Table 2: Acronyms and Abbreviations

Shorthand	**Stands For**
TP	Total phosphorus
TDP	Total dissolved phosphorus
SRP	Soluble reactive phosphorus
NO3-N	Nitrate as nitrogen
UFI	Upstate Freshwater Institute
SUESE	Syracuse University Center for Environmental Systems Engineering
CNAL	Cornell Nutrient Analysis Laboratory
(NYS) DEC	New York State Department of Environmental Conservation
(NYS) WRI	New York State Water Resources Institute at Cornell University
SWCD	Delaware County Soil and Water Conservation District
WAC	Watershed Agricultural Council
WAP	Watershed Agricultural Program
DCAP	Delaware County Action Plan
L Farm	Anonymous "lowland farm" cooperating with WAC and NYS DEC; hosts a continuous surface water sampling station
R Farm	Anonymous upland farm cooperating with WAC and NYS DEC; host a continuous surface water sampling station
TC site	Trout Creek groundwater sampling area
GF site	Hamden groundwater sampling area
HF site	H Farm groundwater sampling area
RF site	R Farm groundwater sampling area; subset of "R Farm"
SR site	Shaw Road groundwater sampling area; control site for NYS DEC surface water sampling
W site	Walton Village groundwater sampling area
(Cornell) BEE	Cornell University Department of Biological and Environmental Engineering
GWLF	Generalized Watershed Loading Functions (simulation model)
SWAT	Soil - Water Assessment Tool (simulation model)
DIW	Deionized water
USDA-NRCS	US Department of Agriculture, Natural Resource Conservation Service

2. Sampling Approach

2.1 Strata and Hypotheses

When locating sampling areas, the project emphasized maximizing likely phosphorus source differences among the sites chosen. Sites were drawn from strata defined by topographic (Figure 1) and land use (Table 3) differences to maximize contrast among sites.

Many DCAP and related research projects about phosphorus in the basin preceded this one (Scott *et al*, 1991; Tolson and Shoemaker, 2004; NYC DEP, 2001; Bishop *et al* 2003; Bishop *et al* 2005; Hively, 2004; NYS WRI, 2002b). These were sufficient to create hypotheses about what general phosphorus levels to expect in shallow groundwater near streams (Table 3). *A priori*, the most mature forest land in upland areas is expected to yield the lowest phosphorus concentrations. Septic system clusters and heavily manured fields with high soil P concentrations should yield the highest concentrations in groundwater. Urban settings with sanitary sewers, which make up a tiny fraction of the basin but which are subject to intense regulation, should fall somewhere in between. Upland areas with fragipan subsoils will probably have higher peak groundwater P concentrations due to limited vertical dilution and limited longitudinal and lateral dispersion to mix effluent with other recharge water. Subsurface retention times in uplands may be weeks to months, and perhaps longer in lowlands due to reduced hydraulic gradients. Differences between upland and lowland time-averaged concentrations will probably be smaller than differences between peaks, and initially it was unknown which setting would yield higher time averages.

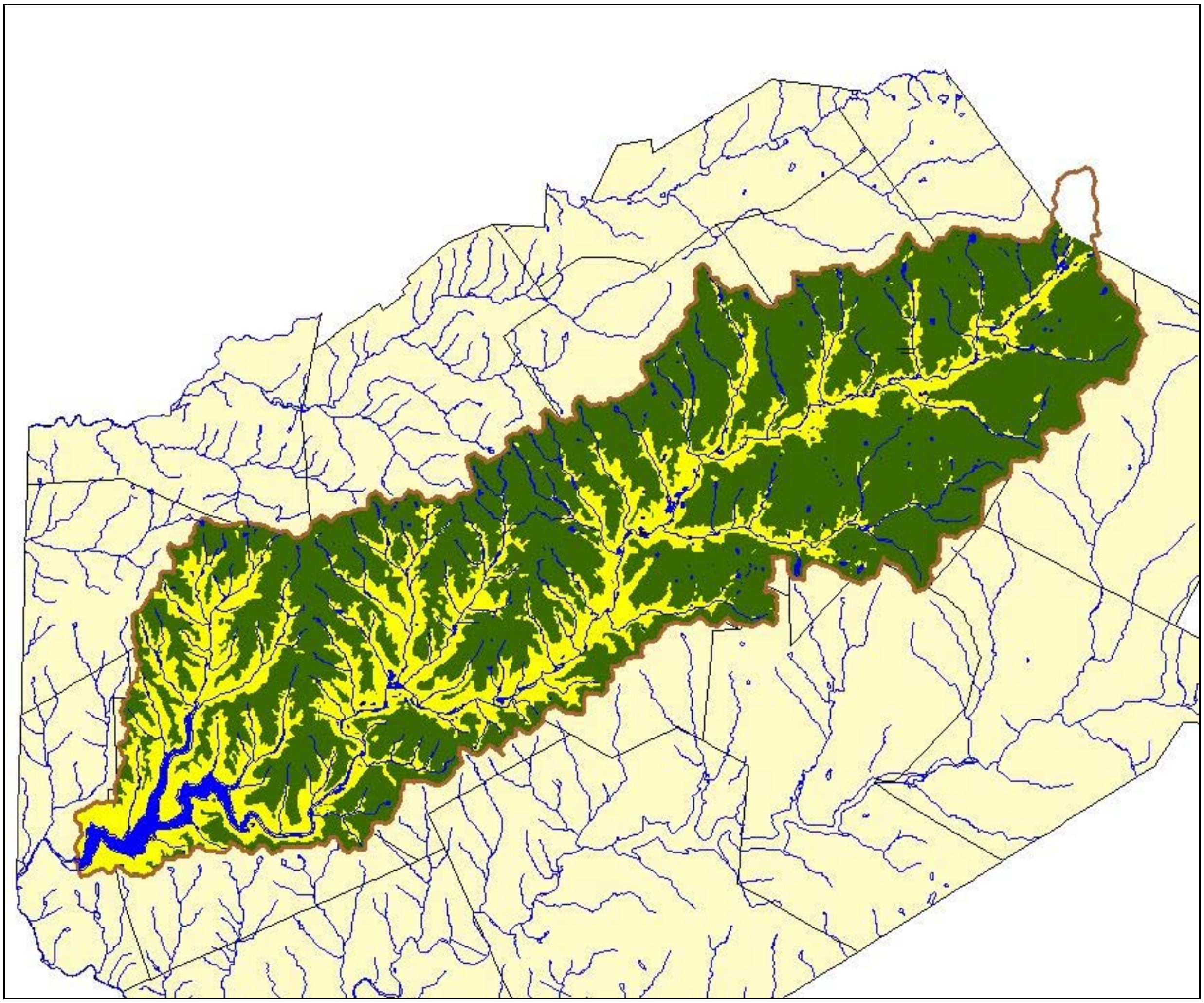

Figure 1: Upland and lowland zones in the Cannonsville basin

Table 3: Strata and hypothesized phosphorus strengths

Land Cover	Phosphorus Sources	A Priori Strength
Mature forest	Soil parent material weathering	LOWEST
Residential area: sanitary sewers	Lawns, Leaky sewers	LOW
Former farm fields and farmsteads	High P fields, Barnyards	LOW- MODERATE (variable)
Active farm fields and farmsteads	High P fields and ongoing manure spreading	MODERATE-HIGH (variable)
Residential areas: septic systems	Septic systems, Lawns	HIGH

2.2 Specific Sampling Sites

Figure 2 shows the sites selected to represent the strata of Table 3. Also shown are NYS DEC's continuous surface water sampling stations, whose data provide an important context for the groundwater work. The "R Farm" and "Shaw Road" areas in this project are also NYS DEC surface water sampling sites.

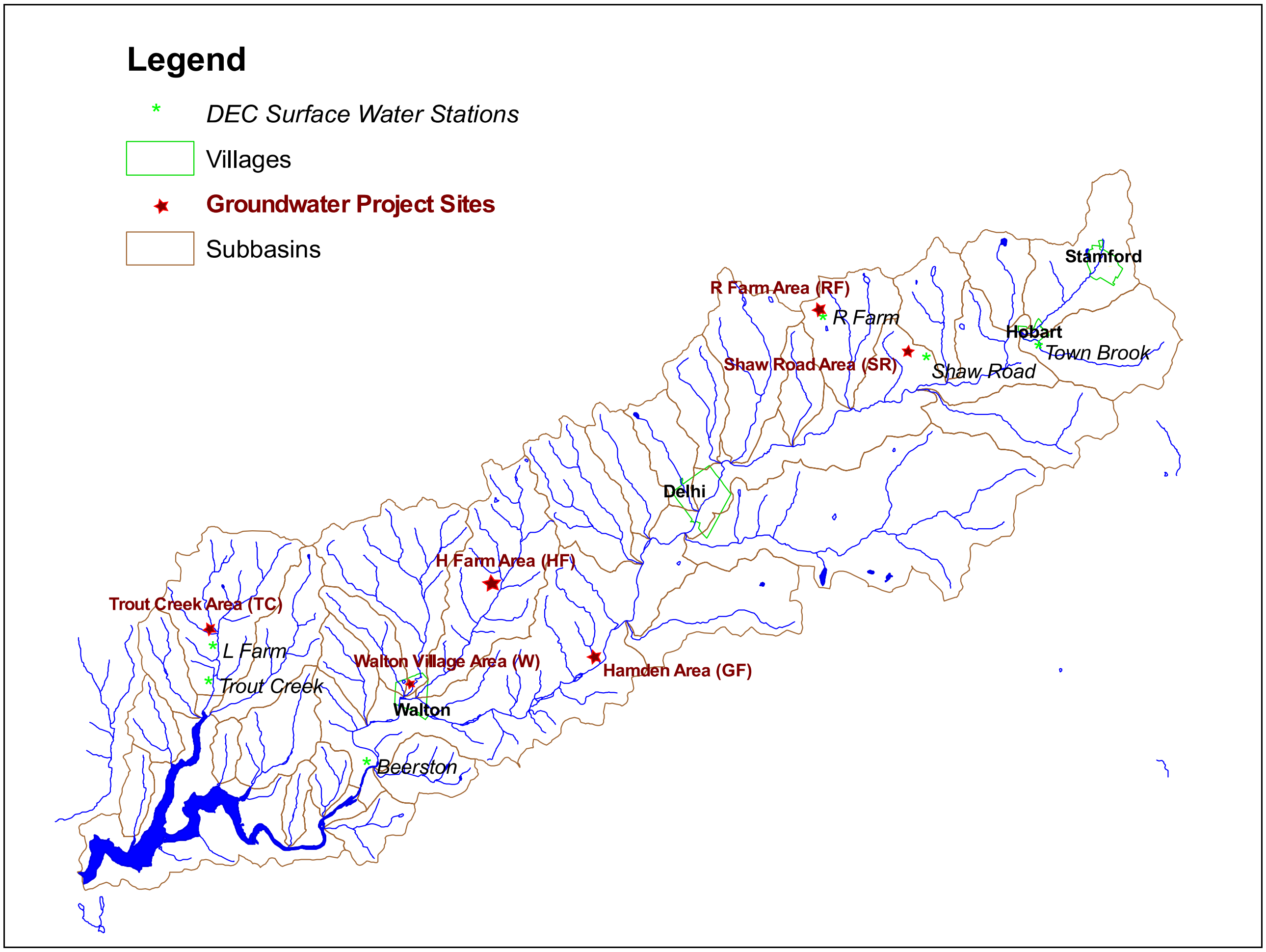

Figure 2: Sampling areas and NYS DEC stream stations

Well placement is critical within sites that have variable phosphorus sources or variable surficial geology. Within a site, placement and depth of wells considered the following aspects:

- How well the location represents groundwater discharging to streams or ponds nearby;
- How reliably the location can be associated with upgradient phosphorus sources, if the sources are small in extent, such as septic systems. It is best to have a single class of phosphorus source rather than a mix of several classes;
- Physical access to install and sample;
- Land owner constraints and preferences;
- Avoiding areas of active construction or other human activity that could change phosphorus sources or local hydrology;
- Feasibility and cost of augering or drilling. Shallower wells are favored in almost all cases; and
- Avoiding possible ponding of water around the well and erosive flows past the well.

Individual septic systems are the smallest sources and it is easy to miss a single plume. Through the cooperation of USDA-NRCS and a regional soil scientist, a geophysical device (a variable frequency electromagnetic profiler) was used initially to prospect for septic system effluent plumes at two residential sites where the location of the plumes was roughly known. However, this instrument was not found to be effective at locating septic plumes at these sites. The project fell back to sampling only areas that had numerous septic systems on small lots, and installed multiple wells in each case.

Table 4 describes the array of individual sampling sites within the six areas shown on Figure 2. Each area included a companion surface sampling site that provided some idea of the quality of surface water that the groundwater discharges into.

Table 4: Sampling Site Details

Name	Location	Upgradient	Downgradient	Total depth from land surface (m)	*A priori* relative P conc	Comments
R Farm, Town of Kortright; upland active livestock farm						
Well: RFW1	East off main road	Grass, (formerly) corn, some grazing, probably some manure spreading	Within marsh, then drainage ditch on east of road; flows under road in culvert to join main stream	0.6	At least moderate	
Well: RFW2	Northeast of pond	Mature forest	Marsh, then intermittent tributary, then pond	0.6	Low	
Well: RFW3	North of pond, at main road	Grass; some grazing and much manure spreading	Drainage ditch along road, then pond	0.8	At least moderate	Water table almost at surface
Well: RFW4	Shortly downstream of DEC station	Rotated corn and grass; 2 years since corn	Main stream (discharge just below DEC culvert)	0.6	At least moderate	Dual well for extra sample volume; oversized excavation
Well: RFW5	Opposite bank from DEC station, just outside of pasture fence	Pasture, frequent grazing	Main stream	0.5	At least moderate	Dual well for extra sample volume; oversized excavation
Tile drain: RFT1	Uphill ~50m from RFW1	(Same as RFW1)	(Same as RFW1)		At least moderate	
Stream: RFS1	Stream at DEC station	Entire farm catchment	Off-property		Highly variable	Sample below small DEC pipe
Stream: RFS2	Along road, eastern tributary to pond	Wetland	Pond		Low	
Shaw Road mature forest and deer farm; upland background						
Stream: SRS1	Stream at DEC station	Entire forest and low-density farm catchment			Low	Sample below small DEC pipe
Spring: SRS2	20-minute hike uphill from new house site	Mature forest	Less mature forest		Low	Sample from small pool below spring outlet.

Name	Location	Upgradient	Downgradient	Total depth from land surface (m)	*A priori* relative P conc	Comments
Hamlet, Town of Hamden; lowland septic systems						
Well: GFW1	At base of hamlet terrace, 100m north northeast from barn	Hamlet with septic systems	Farm field and composting area	2.3	Moderate to high	Screen at bottom about 30 cm; our install
Well: GFW2	Near drainage ditch, about 15m from manufactured housing unit	Hamlet with septic systems; drainage ditch	Farm field, organic vegetables	3.3	Moderate to high	Commercial install; Screen at bottom 150 cm
Well: GFW3	About 3m north-northeast from GFW2	Hamlet with septic systems; drainage ditch	Farm field, organic vegetables	4.9	Moderate to high	Commercial install; Screen at bottom 90 cm
H Farm, Town of Walton; lowland former livestock farm						
Well: HFW1	North part of area down-gradient from old barnyard	Former barnyard, house, stone milkshed, yard	Grassed fields; receive manure	4.8	Low to moderate	Screen is 90 cm; commercial install
Well: HFW2	South part of area down-gradient from old barnyard	(same as above)	(same as above)	4.0	Low to moderate	as above, except screen is 150 cm long and straddles water table
Stream: HFS1	Feak Hollow Brook, at treeline marking H ownership	Mixed forest and farm	Active ag fields		Low	
Spring: HFS2	Spring on slope above west bank of East Brook	Forest and grass/shrub	Forest and grass/shrub		Low	Catchment has not received manure in quite a few years.
Hamlet of Trout Creek, town of Tompkins Highway Dept property; upland septic systems						
Well: TCW1	Edge of highway dept lot, about 30 m from schoolhouse	Houses with septic systems in fragipan soil	Highway dept lot, crushed stone and gravelpiles	4.5	Moderate to high	Commercial install; 150 cm screen straddles water table
Well: TCW2	Edge of highway dept lot, about center between two driveways	(same as above)	Highway dept lot, crushed stone and gravel piles	4.0	Moderate to high	as above

Name	**Location**	**Upgradient**	**Downgradient**	**Total depth from land surface (m)**	***A priori* relative P conc**	**Comments**
Stream: TCS1	Trout Creek north from hwy dept property, 50m above bridge	Mixed rural land use; upstream from most of hamlet	Hamlet		Low?	
Village of Walton, park along West Brook; lowland sewered residential						
Well: WW1	South part of wider clearing in linear park along West Brook	Small lot residential with sanitary and storm sewers	Narrow park with path, West Brook about 20m downhill	4.3	Low?	Commercial install; screen is 150 cm straddling water table; commercial install
Well: WW2	North part of wider clearing in linear park along West Brook	(same as above)	(same as above)	4.6	Low?	As above
Stream: WS1	Side path to stream, below WW2	Village, Austin Lincoln Park	Village		Low?	

2.4 Sampling Duration and Intervals

The project sought to have at least one seasonal cycle per site. Except at Shaw Road, the project sought to have no more than two months between samples. At the R Farm area, the shallow wells were dry at times which made some intervals longer than the 2-month target.

3. Data Collection and Quality Assurance

3.1 Field and Field Lab Procedures

The project's Quality Assurance Project Plans and a Standard Operating Procedures appendix document thoroughly all field and field procedures (NYS WRI, 2005b; NYS WRI, 2005d; NYS WRI, 2005e). This section provides a brief overview.

Water levels in wells were measured with an immersible electrical conductivity device or a closed-end tube that is slapped gently against the water surface inside the well. Temperature, pH, and electrical conductivity were measured within the well or surface water body using a Yellow Springs model YSI-63 meter having a long cable probe. Groundwater samples and spring samples were drawn with a hand-operated vacuum pump or a battery-powered peristaltic pump, after purging to remove 1-3 casing volumes of water. Surface water, tile drain, and spring discharge samples were usually taken by immersing the sample bottle in the stream or drain flow. In a few cases springs were sampled with the hand pump.

Most sample processing was based on NYS DEC procedures employed in parallel surface water sampling work (Bishop and Lojpersberger, personal communications, 2004-2006). In particular, considerable care is necessary to avoid cross-site contamination (using separate hoses for each well), to clean equipment (using large amounts of deionized water for cleaning, and again only using each hose once per sampling time), to wear gloves in field and lab, and to minimize sample holding times and departures from a target temperatures (filtering within 48 hours -- usually within 24 -- and keeping samples refrigerated or iced).

After filtration using a 0.45 micron membrane filter, samples were shipped in insulated boxes with ice via express shippers or hand carried. The Upstate Freshwater Institute (UFI) analyzed for total (dissolved) phosphorus using an EPA standard, manual method having a detection limit of 0.6 µg/L and a quantification limit of 1.5 µg/L. Syracuse University's Center for Environmental Systems Engineering (SUESE) analyzed for selected anions (Cl, NO3, SO4, F) and selected cations (K, Na, Al, Ca, Mg) using automated Ion Chromatography and Inductively Coupled Plasma respectively.

Lab and field blanks were provided to laboratories with most sample batches. The lab blanks consisted of deionized water that has not been passed through any field apparatus. The same deionized water is used for washing apparatus and making up field blanks. Field blanks are prepared through a freshly cleaned hose and pump for each type of hose and pump combination separately. In general, the blanks have revealed that sample processing blurs some results below about 4 µg/L of dissolved phosphorus due to using imperfect deionized water supplies in the field lab at Walton (later replaced entirely with deionized water hauled from Cornell) and due to filtering all samples through the same filtering apparatus. This is an adequate "noise" floor for all but the most pristine sites (SRS2 and RFS2).

At the HF and GF sites, and one other candidate site that was dropped, soil samples were taken before well installation to determine the general phosphorus levels in surface soil. These used customary procedures of the Watershed Agricultural Program and Cornell Nutrient Analysis Lab (CNAL) to obtain samples. See the Forest Soil subproject report (NYS WRI, 2002a) for methods. Samples were stored at room temperature and conveyed to CNAL, who performed their standard Morgan's solution extraction and autoanalyzer analyses.

Late in the project a few samples were analyzed for Soluble Reactive Phosphorus (SRP) at UFI and Cornell's Biological and Environmental Engineering (BEE) lab. The filtered samples for UFI were frozen to inhibit chemical and biological activity; samples to BEE were hand carried and refrigerated since their own project protocol does not use freezing.

3.2 Sampling Periods

Table 5: Sampling Periods and Counts

Period	**Site**	**Wells & springs**	**Tile Drains**	**Streams & ditches**	**Field Blanks**	**Lab Blanks**	**Total**
Nov 2004	*R Farm*	*5*	*0*	*2*	*1*		***8***
	Shaw Road	*1*	*0*	*1*			***2***
Dec 2004	*R Farm*	*6*	*0*	*2*	*1*		***9***
Feb 2005	*R Farm*	*6*	*1*	*2*	*1*	*Walton*	***11***
Mar 2005	*R Farm*	*6*	*1*	*2*	*1*	*Ithaca*	***11***
	Hamden	1	0	1	1		**3**
Apr 2005	R Farm	4	1	2	1	Food Club distilled water	**9**
	Hamden	1	0	1	1		**3**
May 2005	R Farm	5	1	2	1	Ithaca (2, one unfiltered)	**11**
	Hamden	3	0	1	1		**5**
July 2005	R Farm	5	1	2	1	Ithaca, Walton, Food Club distilled	**12**
	Hamden	3		1	1		**5**
	Shaw Road	1		1			**2**
Aug 2005	R Farm	all wells dry	tile drain dry	1 (+RFS2 dry)		Ithaca (filtered)	**2**
	Hamden	2 (+1 dry)		dry			**2**
	H Farm	3		1	1		**5**

Period	Site	Wells & springs	Tile Drains	Streams & ditches	Field Blanks	Lab Blanks	Total
Sep 2005	R Farm	1 (+4 dry)	tile drain dry	1 (+RFS2 dry)	0	Ithaca (filtered & unfilt)	**4**
	Hamden	2 (+1 dry)		dry			**2**
	H Farm	3		1			**4**
	Walton	2		1	1		**4**
	Trout Creek	2		1			**3**
Oct 2005	R Farm	4	1	2	1	0	**8**
Nov 2005	Hamden	3		1		Ithaca (filtered)	**5**
	H Farm	2		2			**4**
	Walton	2		1	1		**4**
	Trout Creek	2		1			**3**
Jan 2006	R Farm	5	1	2	1	Ithaca (filtered & unfiltered)	**11**
	Hamden	3		discontinued			**3**
	H Farm	3		1			**4**
	Walton	2		1			**3**
	Trout Creek	2		1			**3**
Feb 2006	Hamden	3		discontinued		Ithaca (filtered & unfiltered)	**5**
	H Farm	3		1			**4**
	Walton	2		1	1		**4**
	Trout Creek	2		1			**3**
Apr 2006	R Farm	5	1	2		Ithaca (filtered & unfiltered)	**10**
	Hamden	3		discontinued			**3**
	H Farm	3		1			**4**
	Walton	2		1	1		**4**
	Trout Creek	2		1			**3**
Jul 2006	Hamden	3				Ithaca (filtered & unfiltered)	**5**
	H Farm	3		1			**4**
	Walton	2		1	1		**4**
	Trout Creek	2		1			**3**
cumulative	**(all)**	**125**	**8**	**49**	**19**	**20**	**221**

Note: Work at R Farm and Shaw Road sites was partially funded under a parallel project through March 2005, and became part of this project on April 1, 2005. The Hamden, H Farm, Trout Creek, and Walton sites are entirely under this project. Italicized samples were also reported in the R Farm parallel project's quarterly reports and final report.

3.3 Quality Assurance

Table 6 summarizes the one-time and recurring quality assurance tests carried out in the project.

Table 6: Lab and Data Quality Assurance Tests

Type	Purpose; Notes	When	Samples Involved	Results
1. Field blanks	Check equipment washing, establish a noise floor; sampled from Cornell DIW through clean hose in field, two blanks when using both peristaltic pump and suction pump within a round (due to different hoses)	All sampling rounds	1 or 2 per round; 19 total	Noise level is about 4 µg/L TDP in samples. (UFI lab cites 1.5 µg/L as their quantification limit). Field blanks are indistinguishable from lab blanks -- well purging and hose washing was adequate.
2. Lab blanks - filtered	Check equipment washing; poured from Cornell DIW, Walton DIW, or Food Club distilled water directly into filter apparatus (no hoses)	Most sampling rounds	one in most rounds; 12 total	Filtered field blanks and filtered lab blanks were very similar in all parameters --apparatus washing including in-field purging of hose was effective
3. Lab blanks - unfiltered	Check filtering process; poured from Cornell DIW directly into final lab bottles	Selected sampling rounds; always paired with a filtered lab blank	2 total	Indistinguishable from filtered lab blank-- filtering did not add notable residue to samples.
4. Splits with CNAL	Cross-lab check of most parameters; CNAL vs. SUESE and UFI.	Dec 2004 and Feb 2005	6 samples including two field blanks, all from R Farm	P resolution at CNAL too low to use their lab for cross-checking R Farm samples; their other apparatus is too different from Syracuse U to yield comparable data; no more splits with CNAL
5. Splits with NYS DOH and Severn-Trent for Nitrate	Determine if low nitrate values in field samples (result much less than field blank) at some R Farm sites is realistic; samples split among Syracuse U, NYS DOH, and Severn-Trent Inc.	One time, RFW4 site plus field blank	2 to each of three labs	Confirmed that nitrate in blanks and field samples is realistic

Type	Purpose; Notes	When	Samples Involved	Results
6. Splits with NYS DOH for TDP and SRP	Compare SRP vs. TDP in selected wells, compare TDP against UFI TDP		4	UFI and DOH are close for both SRP and TDP analysis; TDP and SRP data are close, i.e. most of TDP is SRP
7. Splits with Cornell BEE	Compare SRP (BEE and UFI) vs. TDP (UFI) in selected wells, as a general check of usability of SRP data from Cornell BEE together with TDP data from UFI.	April and July 2006 sampling rounds; SRP at UFI in July only	5 + 5	UFI-TDP data are comparable to BEE SRP data above around 10 µg/L; BEE is higher for blanks; UFI SRP and TDP data very close at all sites
8. Filtering order test - blank first or last	Determine carryover between samples in filter apparatus (washing effectiveness); normally blanks are filtered first, at one round the blank was filtered last	Once	1	Washing of filter apparatus was okay
9. Laboratory duplicates	Determine repeatability; labs analyzed some samples twice during each round	All sampling rounds; lab chose which samples to repeat	15 at UFI, 14 or 15 at Syracuse U	All results are comparable; labs may not have reported problematic samples (some were reported as "failed QA")
10. Outliers test	Determine individual measurements that have much effect on parametric statistics; standard EDA techniques for identifying high and low outliers within a distribution, when a distribution is defined as all results from a single site over time	(reporting)	(not applicable)	Outliers excluded from statistical summaries

Table 7 reports the phosphorus results from test 4 in Table 6. CNAL was chosen as the second lab since they have tested nearly all of the soil samples in the watershed agricultural program for phosphorus. They use an autoanalyzer which is poor at resolving levels below 20 µg/L. (UFI's procedures have been tested before by DEC and others; their quoted quantification limit of 1.5 µg/L is reasonable.) In one sample CNAL quoted a detection limit of 18 µg/L, but actual values were reported below this in all other samples.

Table 7: Early Cross-Lab Check for R Farm Samples

Site	**Date**	**CNAL TDP (µg/L)**	**UFI TDP (µg/L)**
RFFB	2004-12-16	<18	<0.6
RFW2	2004-12-16	7.2	6.2

Site	Date	CNAL TDP (µg/L)	UFI TDP (µg/L)
RFFB	2005-02-09	9.3	1.8
RFW1	2005-02-09	9.3	11.8
RFW2	2005-02-09	12.9	18.0
RFW4	2005-02-09	15	12.1

CNAL was no longer used for sample splits after February 2005 due to the limited range of their equipment.

Tests 6 and 7 in the above table 6 provided especially useful results. The four-laboratory cross check in July 2006 was done among forms of phosphorus -- TDP and SRP -- and between two pairs of labs, UFI versus Cornell BEE, and UFI versus NYS DOH. The BEE lab was included to help in future blending of data from the parallel “lowland farm” project. Table 7 provides the test results.

Table 8: Results of Cross-Parameter and Cross-Lab Comparisons (values in µg/L)

Site (1)	Date (2)	BEE SRP (3)	UFI SRP (4)	UFI TDP (5)	DOH SRP (6)	DOH TDP (7)
GFW1	20060717			14	14	13
GFW2	20060717	135	162	158		
GFW3	20060717			74	76	70
TCW1	20060717			33	32	32
TCW2	20060717	86	103	104		
WFB*	20060717	10	0.4	1.5	<1	<2
WW1	20060717	35	39	39		
WW2	20060717			32	30	29
WFB*	20060424	8.2		<0.6		
HFW1	20060424	40.9		41		
GFW3	20060425	54.2		54		
RFW3	20060425	13.5		10		

(* field blank)

These data have several interpretations:

- BEE's SRP versus UFI's (3rd and 4th columns): The higher values (above 10 µg/L) are acceptably close. Values around the magnitude of the field blank (under 2 µg/L) are probably biased high at Cornell BEE's lab, below their effective quantification limit which may be similar to CNAL's at 10-20 µg/L P.
- SRP and TDP from these well samples and field blanks are very close (4th vs. 5th columns, 6th vs. 7th columns). Both UFI and DOH labs had essentially the same results.
- UFI and DOH TDP results are very close, for the samples split between them.

The above was sufficient assurance that BEE's SRP results for the Lowland Farm can be interpreted together with the UFI TDP results for all other sites without adjustments. (It would have been helpful to also cross-check with UFI analyzing water from the Lowland Farm wells; unfortunately the Lowland Farm wells had all been removed before the use of SRP methods was discovered.)

3.4 Analytical Results Database

All field and laboratory analytical results were stored in a database at NYS WRI. Periodic snapshots were sent to all project staff and principals. Laboratories reported results in spreadsheets or on paper, which were transcribed into the common database format. Field data (such as pH readings) were recorded initially in field logbooks then transcribed into the database. Transcription was all done by one person who participated in all sampling and received all lab results, helping to standardize and cross-check all data before it was considered usable in interpretations.

4. Results and Discussion

4.1 Water Quality

Overview

Table 9, Figure 3, and Figure 4 summarize dissolved phosphorus and nitrate results at individual sampling points. Appendix B provides summaries of many more parameters measured.

In general, surface water samples -- except from the R Farm RFS1 site at the DEC monitoring station -- have much lower phosphorus and nitrate concentrations than nearby wells. This may indicate that the project's site selection process was good at finding higher intensity phosphorus sources and at placing wells. The Trout Creek (TCS1), H Farm (HFS1), and Walton (WS1) companion surface sites all have a considerable fraction of forested land in their catchments in major contrast to land uses near the related wells.

The bar charts in Figures 3 and 4 order sites vertically from low to high *a priori* expected phosphorus concentrations. (Nitrate being more mobile than phosphorus in soil, and source strengths of the two nutrients also being different, the ordering is much less significant in Figure 3 than in Figure 4. The consistent ordering intends to allow easier comparison between the figures.)

Built up areas, including the Walton Village area with sanitary sewers, contributed the most nitrate and the forested background sites the least. GFW3 and TCW2 in the septics areas were notable for occasional values above 10 mg/L, a drinking water criterion. (Fortunately there are no drinking water wells in the vicinities.) The former barnyard (HF) and active dairy farm (RF) yielded values somewhat above the forested sites. It was somewhat of a surprise to see nitrate enrichment in the sewered Village of Walton.

The vertical ordering by *a priori* phosphorus concentration also reveals that actual phosphorus ranks (Figure 4), were predicted well, with one notable exception. Shallow wells at the RF site (active dairy farm) yielded unexpectedly low TDP concentrations. This is discussed in greater depth in a subsection below. Hamlets with septic systems yielded the highest TDP medians of any area type, and yielded the highest individual values with the exception of a tile drain at RF.

The following subsections provide interpretations of groundwater data within sites.

Table 9: Summary of Dissolved Phosphorus and Nitrate Sampling Results (µg/L)

Site	TDP Count	Low	Median	High	NO_3-N Count	Low	Median	High
RFW1	10	3.8	8.6	28.6	9	7	43	1,608
RFW2	9	6.2	18.0	36.6	9	606	782	1,332
RFW3	10	3.4	12.3	25.5	10	162	1.413	2149
RFW4	11	8.1	18.7	49.5	11	4	35	149
RFW5	9	6.8	11.8	21.3	8	2	59	2,169
RFS1	12	11.5	39.0	160.4	10	131	513	1674
RFS1-event[a]	*476*	*10*	*50*	*580*	*476*	*90*	*580*	*3,020*
RFS1-non[b]	*1621*	*10*	*30*	*320*	*1,621*	*20*	*380*	*1,730*
RFS2	9	2.5	8.3	23.9	8	9	288	637
RFT1-tile	8	17.4	49.9	155.9	7	1.086	1,355	3,577
RFFB[c]	9	<0.3	1.4	3.8	9	10	141	218
SRS1	2	4.4	7.8	11.1	2	15	36	57
SRS1-event[d]	*382*	*4*	*10*	*29*	*382*	*10*	*100*	*940*
SRS1-non[e]	*1715*	*<1*	*7*	*20*	*1715*	*<10*	*60*	*1300*
SRS2-spring	2	1.4	8.3	15.1	2	159	258	356
TCW1	6	11.9	28.7	38.6	6	2,843	3,388	5,519
TCW2	6	18.9	82.8	107.8	5	7,384	8,781	11,927
TCS1	6	5.0	10.4	23.5	6	153	300	406
WW1	6	27.4	29.7	38.6	6	1,672	4,754	6,007
WW2	6	26.5	30.5	38.3	6	804	4,929	6,166
WS1	6	3.7	10.4	45.6	6	242	591	814
WFB[f]	5	<0.6	<0.6	1.5	5	9	108	226
HFS1	7	3.7	5.2	22.2	7	28	157	192
HFS2	7	3.3	17.2	20.8	7	120	189	267
HFW1	7	41.0	48.0	62.0	7	83	951	1,425
HFW2	7	39.4	48.6	170.1	7	218	784	1,154
GFW1	9	3.5	9.1	162.6	9	618	1,801	4,926
GFW2	9	70.0	96.5	176.5	9	1,373	2,318	8,101
GFW3	9	32.2	63.4	87.1	9	1,970	5,180	11,883
GFFB[g]	4	0.6	1.7	4.2	4	140	202	216

aNYS DEC data
bNYS DEC data
cField blank
dNYS DEC data
eNYS DEC data
fField blank
gField blank

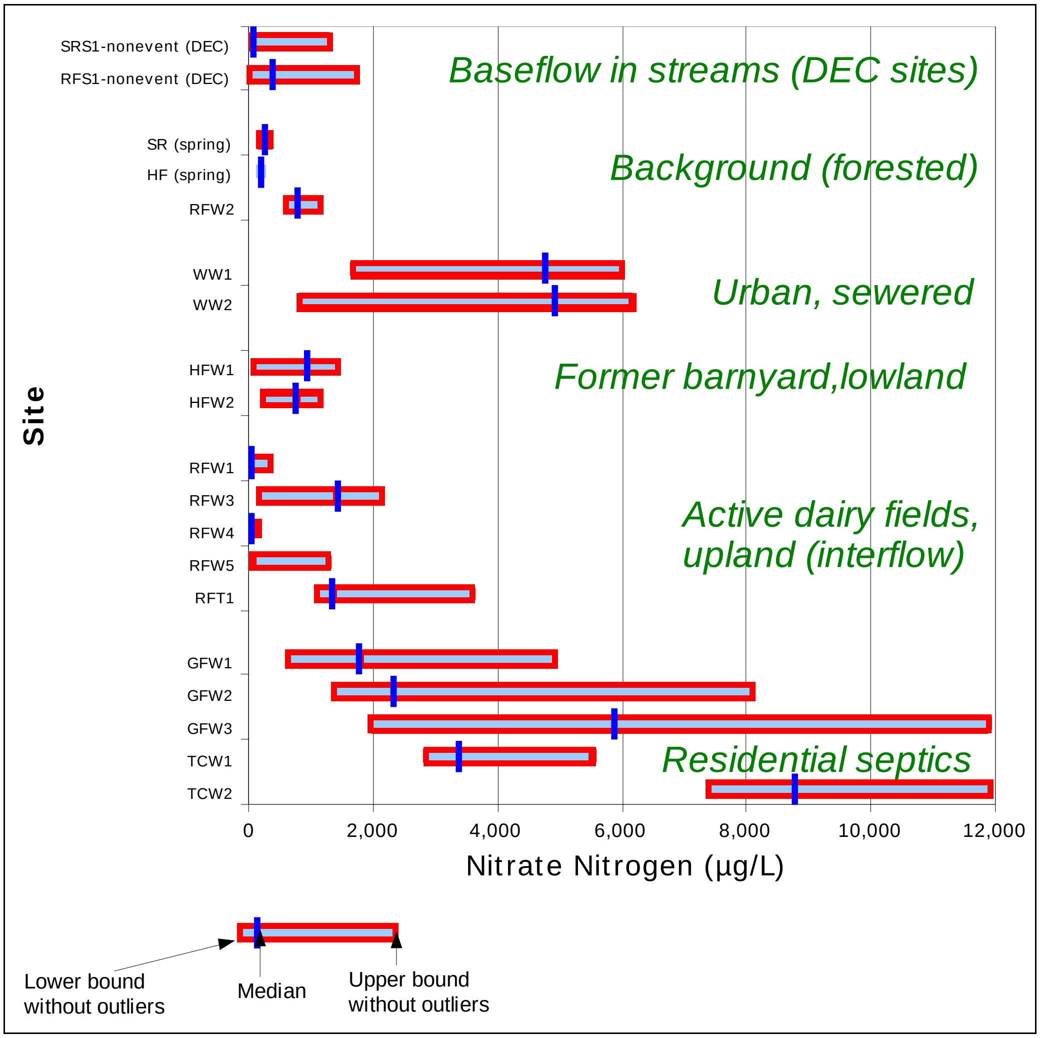

Figure 3: Median and variability of nitrate nitrogen values from all sites, plus baseflow values in two reference streams

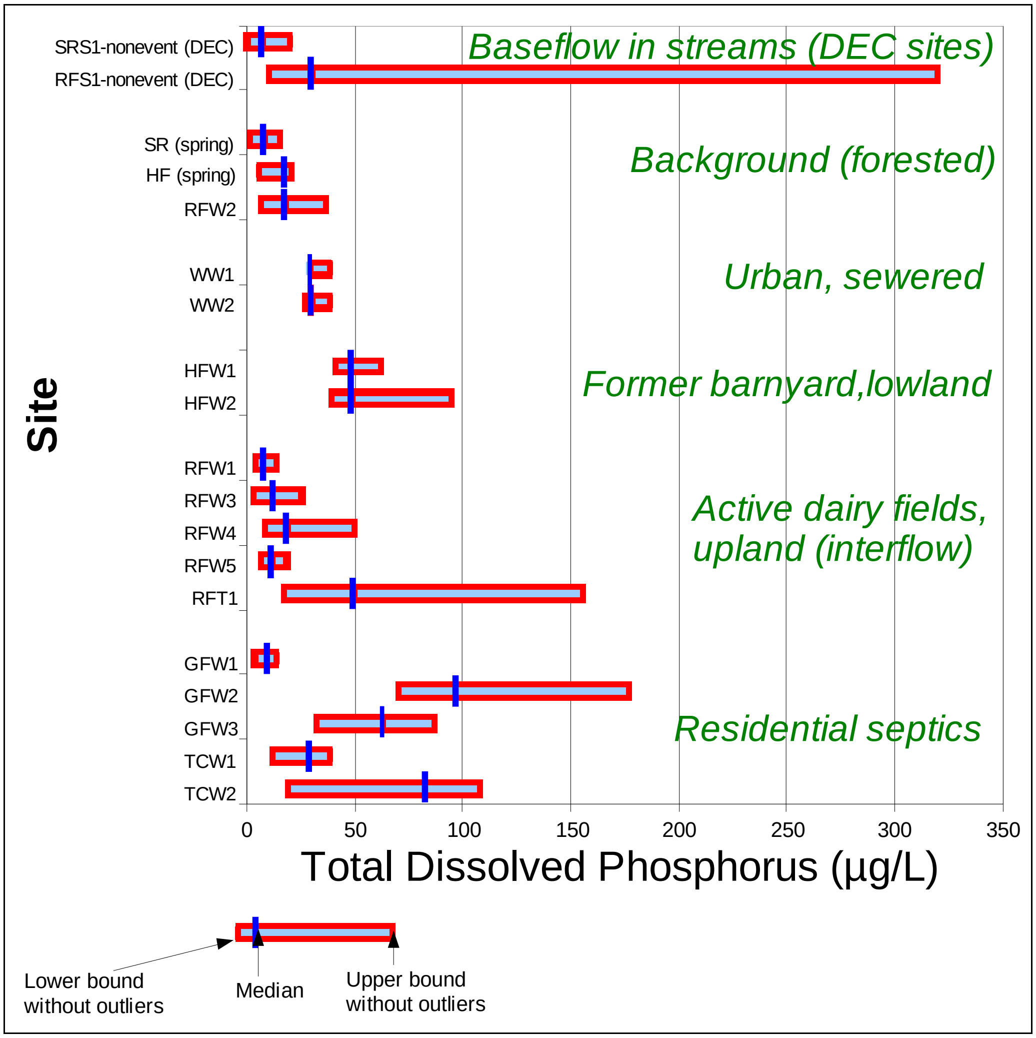

Figure 4: Median and variability of Total Dissolved Phosphorus values from all sites, plus baseflow values in two reference streams

Figure 5 illustrates seasonality of TDP in a few contrasting wells. Fall tended to yield a higher concentration than spring or summer. Figure 5 also illustrates that variability increases with increasing median concentrations.

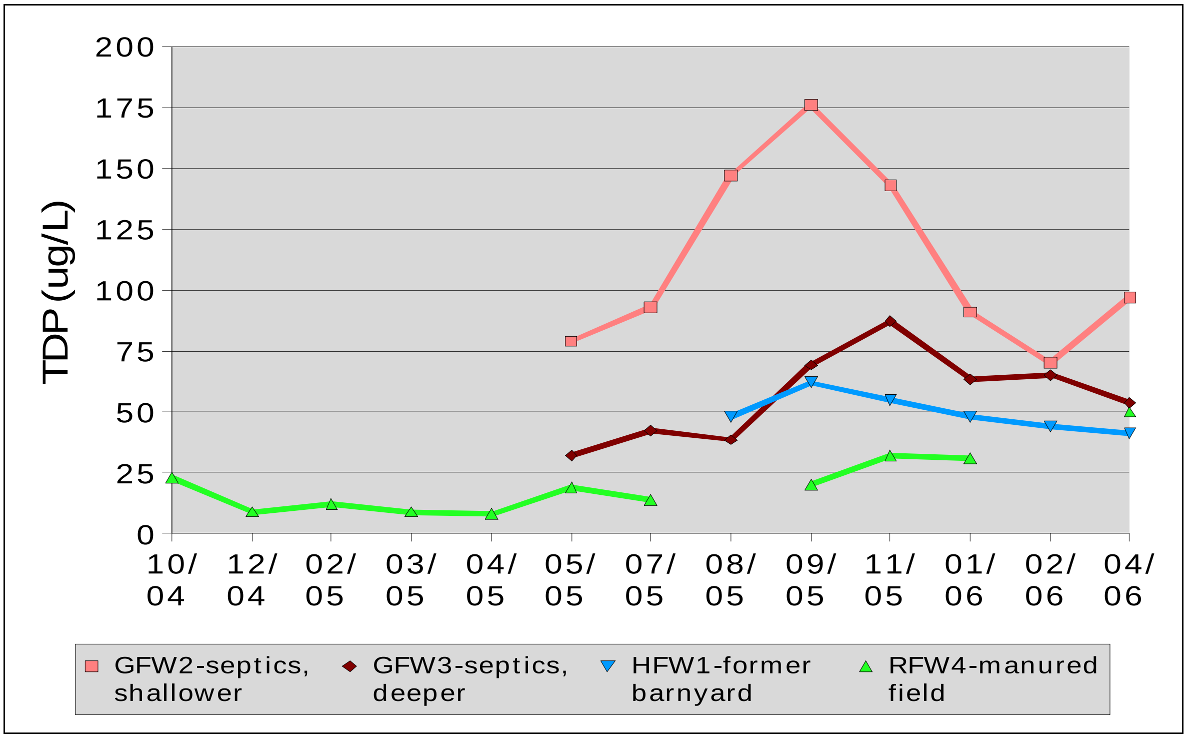

Figure 5: Time series of Total Dissolved Phosphorus at four wells

R Farm Site (Upland active farm)

The R Farm wells were installed in late 2004; more analyses are available here than at other sites. All wells there were installed at depths less than 1.2m. An existing tile drain began to be sampled in early spring, 2005. These sampling points are considerably different than at other project sites, in that they sample perched, very transient water tables instead of an area's persisting water table below any fragipan. Several attempted samplings at some R Farm wells came up "dry", during a dry summer 2005.

After almost two full seasonal cycles of samples, ranges and median values of total dissolved phosphorus (TDP) have been notably lower in groundwater samples than in the downstream (RFS1) surface water location and in the tile line discharge. Considering the well data alone (RFW1 - RFW5), a forested site (RFW2) that has had little or no P inputs from agriculture in recent decades appears to have higher TDP values (median = 18 µg/L) than do wells downgradient from the active farm fields (medians = 8.6 to 18.7 µg/L). Values in the wells other than RFW2 seem low in comparison to those at most other sites and a priori expectations for manured fields, and in RFW2 values are higher Perhaps a monthly to bimonthly sampling calendar in the very shallow wells suffers from the same problem that widely spaced samples have in highly variable surface water -- a low bias because peak concentration periods are so short and peak flows carry a disproportionately high fraction of annual solute load due both high flows and high concentrations coinciding. The cooperating "Lowland Farm" project also sampled very shallow groundwater and observed highly transient phosphorus concentrations in its piezometers (Flores-Lopez, personal communication, 2006).

Nitrate in wells RFW1, RFW4, and RFW5 is quite low, below even that in deionized water blanks. RFW1 and RFW4 are in very wet areas, RFW1 within a perennially wet area where knee boots were required for access, and RFW4 in an area where there was clearly occasional overland flow. RFW3 had much higher nitrate than these two despite very similar upgradient land uses. During a Scientific Support Group meeting, discussants commented that the very low nitrates were in settings where waterlogging of soil could produce anaerobic zones that foster denitrification. RFW3's setting also had a piezometric head near the surface during most sampling periods but had firm soil and lacked wetland plants. Denitrification differences seem plausible.

For comparison, Table 9 (above) included unpublished results from NYS DEC stream sampling at the R Farm (*RFS1-event*, and *RFS1-non*) and Shaw Road (*SRS1-event* and *SRS1-non*), summarized for the period November 1996 through July 2002. The "-event" and "-non" suffices represent days DEC classified as being influenced by rain or snowmelt events, or not influenced by events, respectively (data from Bishop *et al*, 2005, unpublished). The "high" and "low" values in the DEC table rows and ranges in all figure bars omit probable and suspected outliers.

The project's samples at RFS1 and SRS1 yielded data within the ranges observed by DEC in baseflow over several years at the same respective locations.

Shaw Road

NYS DEC's control site for its R Farm sampling also provided a stream baseflow and groundwater site for this project. The owner identified the latter, a well protected upland spring that the owner intended to use as a domestic water supply source for a new house. The spring represents the highest quality area within a high quality catchment having minimal human phosphorus imports.

Only two samples at a half year interval were taken due to the lack of any strong P sources and minimal seasonality in NYS DEC's baseflow data (unlike at R Farm). The results were consistent with earlier DEC baseflow sampling, and yielded the single lowest TDP concentration measured at 1.4 µg/L, around the level of field and lab blanks made from deionized water. Unsurprisingly, the area is the best background site in this project.

Hamden Site (Lowland septic systems)

At the G farm (Town of Hamden), GFW1 was installed in early 2005, while the remaining wells

GFW2 and GFW3 were installed in spring 2005. The wells are downgradient from the hamlet of Hamden, which uses individual onsite septic systems for wastewater treatment, many of which are purported to not be functioning properly. Well GFW1 skimmed the top 0.7m of water table at the time of installation, while wells GFW2 and GFW3 straddled and penetrated 1.5 meters below respectively. GFW3's screen is short, so it reflects piezometric head at a deeper level and GFW2 has a long screen to represent head just below the water table (of course varying with seasons). GFW2 and GFW3 are about five meters apart laterally, and perhaps 100 m from GFW1.

GFW1 has yielded highly variable results that may be influenced by a fluctuating water table that dried the well up completely at times. GFW2 and GFW3 results are probably the most representative of local groundwater.

GFW2's and GFW3's qualities have been consistent in their relationship to one another. The GF bars in Figures 3 (nitrate as N) and 4 (TDP) indicate that relative phosphorus and nitrate levels are inverted between the pair, with the deeper well yielding less phosphorus and more nitrate. Nitrate at both wells is several times higher than in any well at R Farm. The high TDP and nitrate support the hypothesis that the wells are indeed tapping into plumes from septic systems.

Trout Creek Hamlet (upland margin septic systems)

The Trout Creek, Walton, and H Farm wells were installed in summer to fall 2005 thus have relatively shorter periods of data than the GF and RF sites. In each case the pair of wells is relatively close together (within 30m), representing an attempt to capture local-scale, lateral and depth variability of groundwater downgradient from a fairly uniform source.

Despite their closeness, TCW1 and TCW2 yield markedly different chemical content, consistently across all four sampling times. TCW1's nitrate and phosphorus concentrations are about half the concentrations observed at TCW2. The HF and WW pairs are much more internally consistent, except for one unusually high TDP result from HFW2 that may be an outlier. One plausible explanation of the great difference between TCW1 and TCW2 qualities would be if TCW1 missed septic system plumes and TCW2 intercepted one.

Village of Walton (residential area with municipal sewerage)

Quality in the two “W” wells was almost identical. The only surprise was elevated nitrate, with medians about 5 mg/L. As indicated above, exfiltration from sanitary sewers uphill from the wells or perhaps an interceptor running along the stream corridor could contribute. Overfertilization of nearby lawns upstream and uphill from the wells might also contribute. Phosphorus was above background but well below the concentrations seen in the septic system areas. Higher nitrate and moderate phosphorus could indicate that soil retention capacity for P has not yet been exhausted by fertilization.

H Farm, Town of Walton (former dairy farm)

Two wells were installed in summer 2005, at the downhill edge of a former barnyard. Soil samples along this edge yielded a Morgan's P level of about 60 kg/ha to 30 cm depth. Deeper subsamples within the 30 cm were similar in P to shallower subsamples. It was as expected -- the barnyard after about 15 years without animals had soil to tell its history. The wells yielded expected elevated P results. The wells had slightly different depths, but very similar qualities unlike the pairs at Hamden and Trout Creek.

The family recommended a protected upland spring on their property as an additional sampling site, later named HFS2. This bedrock niche yielded high quality water, approaching the best in the project (SRS2 and RFS2).

Anion and Cation Balances

"Major" ions are those that comprise the majority of dissolved constituents in ground and surface waters. Typically these include cations of sodium, potassium, magnesium and calcium, and the anions chloride, bicarbonate and sulfate[1]. The trilinear diagram can be used to plot ratios of cations and anions, which can become the basis for a useful classification scheme for natural waters (Fetter, 1988).

Figure 6 shows a Piper diagram of combined trilinear diagrams for both anions and cations at a series of sampling events from one lowland site. The ion balance from samples taken from wells and from nearby spring and stream were found to plot in distinctly different areas of the figure, implying that fundamental differences exist. Groundwater from the wells was of the sodium-chloride type, while the spring (located on the adjacent valley sidewall, in uplands) and stream had no dominant cations or anions. Circles around well data points indicate the amount of total dissolved solids—around 500 ppm for well samples, near zero for spring and stream samples. During spring (April sampling event, both wells), sodium and chloride was overwhelmingly dominant, implying that deicing salt applied to the nearby road may be influencing the shallow groundwater.

Figure 7 shows ion balance from several upland sites. Ground water from wells RFW1–RFW5 in active farm fields in uplands is quite similar to groundwater from the upland spring used as background levels of TDP, and to the stream originating on the farm. Calcium is the dominant cation, bicarbonate the major anion, and very low levels of dissolved solids.

[1] [1] Bicarbonate was calculated from field measurements of pH and temperature, combined with lab measurements of other major ions.

In general, all lowland sites had a major ion balance similar to those from wells in Figure 6 and substantial amounts of dissolved solids. In contrast to this, all (five) wells in the upland site, two springs and the surface waters sampled had major ion balances similar to that of Figure 7 and low amounts of dissolved solids. It appears that the streams sampled in this study, in either upland or lowland settings, closely reflect their origins in uplands. Ground waters from our lowland settings have characteristics different from those in uplands, and different from the streams that the lowland ground water discharges to.

Elevated levels of dissolved solids in lowland ground water arises from natural sources (longer travel time between ground water recharge in uplands and its eventual discharge in lowland valley settings allows increased solution of constituent minerals), and from human activities. The extent to which human activities influence groundwater constituents might have been clarified, beyond the likely influence of road salt, if a long-term forested site could have been located for establishing background conditions in a lowland setting; however, no suitable site was located during the duration of the project.

As a further note about general ground water characteristics, samples from all sites were moderately acid to neutral in pH, and quite "soft" (very under-saturated with calcium and magnesium ions).

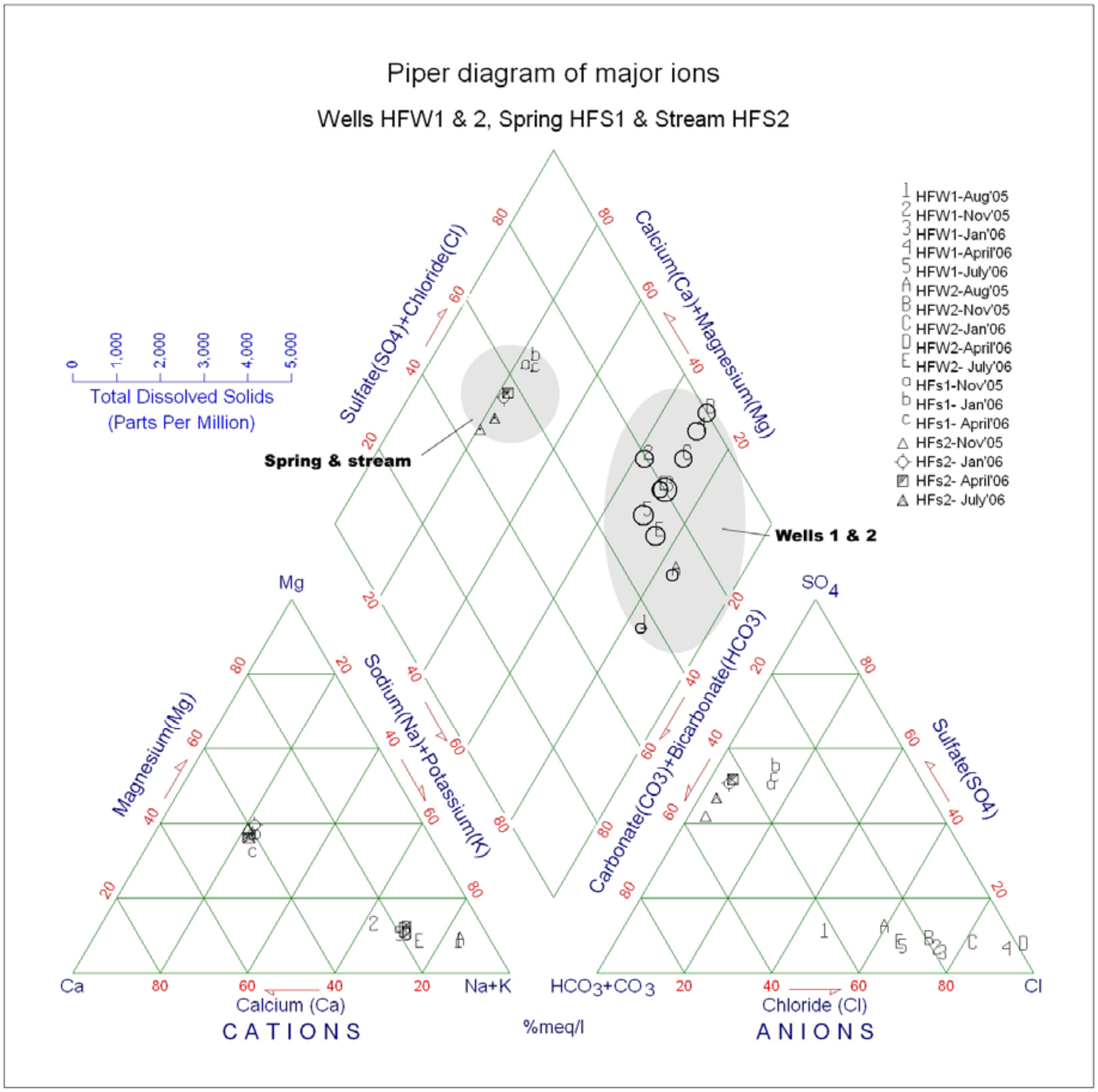

Figure 6: Anion and cation balance at one upland sample site

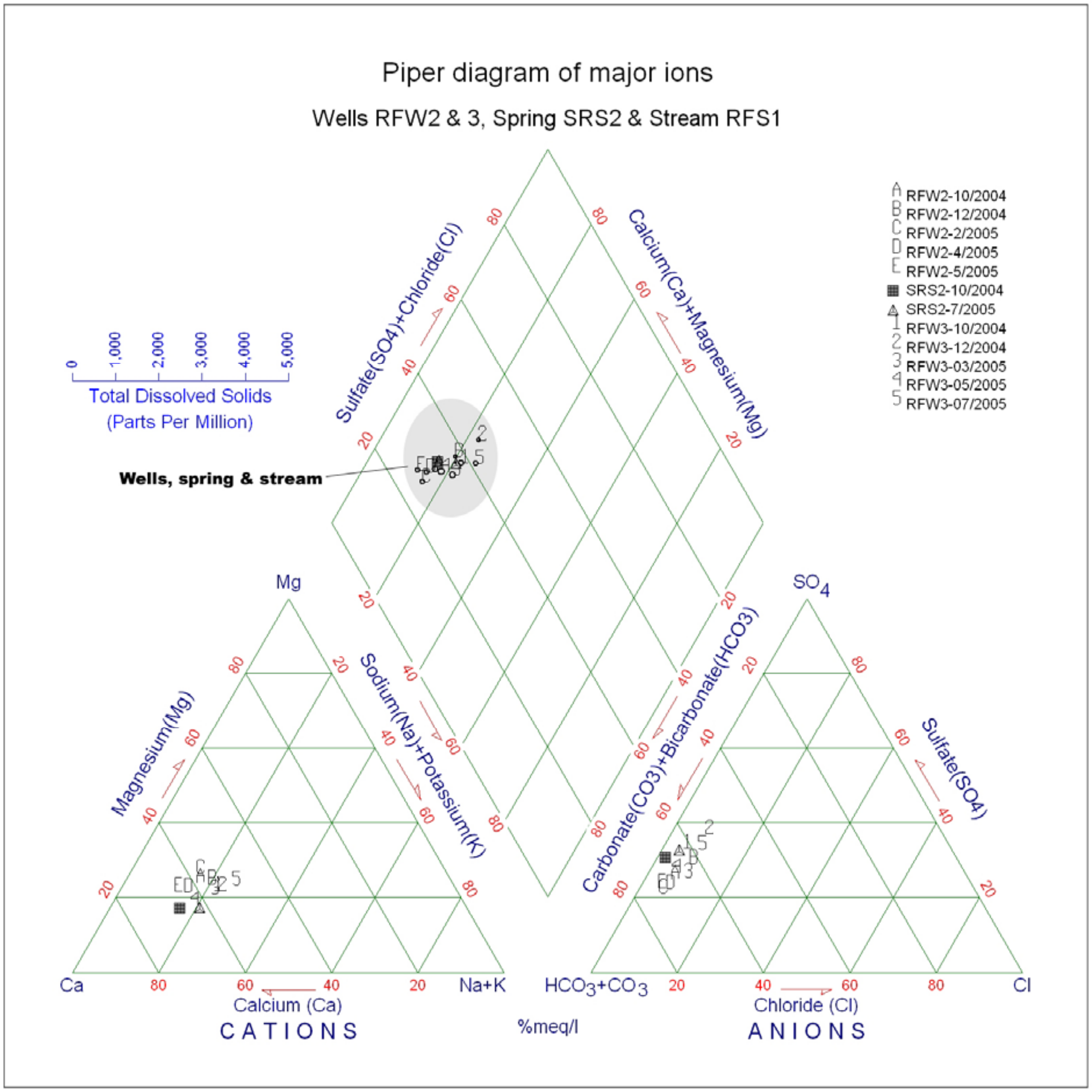

Figure 7: Anion and cation balance at upland sample sites

Wastewater Indicators Sampling in Relation to Septic Systems

Because phosphorus and nitrate come from many sources in the environment, they are not perfect indicators that wells intersect with septic system plumes. SWCD's and WRI's experience with septic system siting and performance, soils, and shallow groundwater all were applied to have the best chances of placing wells within plumes. The inorganic chemical and physical measurements made in the project were consistent with certain wells being in plumes (TCW2, GFW2, GFW3) and certain wells missing plumes (GFW1, TCW1, all wells at other sites except a slight chance at HFW1 and HFW2) . However, literature suggests that individual system plumes do not spread very far laterally or vertically thus parameters more unique to wastewater were sought to corroborate in-plume or non-plume positioning. The project took soundings about individual indicators including caffeine, which yielded an offer from the USGS Water Resources Division office in Ithaca to assist by advising about field protocols and providing laboratory services to test for a list of several dozen wastewater indicator parameters that they use nationally.

In July 2006 WRI and SWCD sampled four sites using USGS' trace organics protocol -- GFW2, HFW1, HFS2 (spring), and TCW2 -- and prepared one field blank with USGS certified blank water. HFS2 has no wastewater sources above it, TCW2 and GFW2 have high nitrate and phosphorus and should have septic system influences, and HFW1 was probably unaffected by septics. (Inorganic chemistry results are much more consistent with old barnyard influence). HFW1 does have a septic leachfield above it serving a single person in one household. USGS filtered the samples (with SWCD assistance) and conveyed them to their laboratory.

The results were effectively "not detected" for every parameter in every sample. The analytical methods provide a high enough resolution for something to have shown up if the samples contained it. USGS-Ithaca staff do not believe that this consistent a result would be related to minor variations in field techniques. Since most of the indicators are subject to chemical or biological degradation in septic tanks and leach fields, the completely blank results could indicate degradation in soil. Most USGS sampling in NY for these parameters is in wastewater collection systems, treatment plants, and streams near wastewater treatment plant effluents. Thus an attempt to clarify well positioning relative to plumes led to another puzzle.

4.2 Water Table Variability

Water levels in the monitor wells (Table 10) have fluctuated considerably, particularly between the relatively wet spring and summer 2005 and the dry winter 2005-2006. Several wells at R Farm went dry during summer 2005, recovering by September. The deeper commercially installed wells at Hamden (GF), H Farm, Trout Creek, and Walton all had plenty of water to sample at all times.

Table 10: Water Table Depth Ranges at Monitor Wells

Site	Total Well Depth, Land Surface to Bottom (m)	Count of Valid Level Measurements	Min Depth Land Surface to Water (m)	Median Depth (m)	Max Depth (m)
GFW1	2.31	9	1.08	1.88	2.13
GFW2	3.32	9	0.91	1.73	2.38
GFW3	4.88	9	0.89	1.68	2.21

Site	Total Well Depth, Land Surface to Bottom (m)	Count of Valid Level Measurements	Min Depth Land Surface to Water (m)	Median Depth (m)	Max Depth (m)
HFW1	4.77	6	0.63	1.46	1.80
HFW2	3.96	6	0.82	1.52	1.85
RFW1	0.61	13	0.08	0.13	>0.61
RFW2	0.62	13	-0.09	-0.05	>0.62
RFW3	0.75	12	0.00	0.05	>0.75
RFW4	0.63	13	0.10	0.23	0.62
RFW5	0.53	13	0.06	0.14	>0.53
TCW1	4.47	5	1.90	2.53	3.48
TCW2	3.97	5	1.86	2.36	3.08
WW1	4.33	5	2.05	2.32	2.99
WW2	4.56	5	2.55	2.95	3.44

negative values indicate artesian pressure; > symbol indicates that the well was dry

Figure 6 shows the history of water levels of two nearby wells at the former H farm site in the Town of Walton. The wells are around 20 meters apart, and their screens were at the water table at installation time (HFW2) and 0.8m below the water table (HFW1). The deeper well (HFW1) had consistently higher piezometric head than the shallower well (HFW2), indicating that this is an area of upward flow. The topographic position of the two wells suggests that this is a discharge area.

A similar relationship holds for the Hamden pair GFW2 (shallower) and GFW3 (deeper).

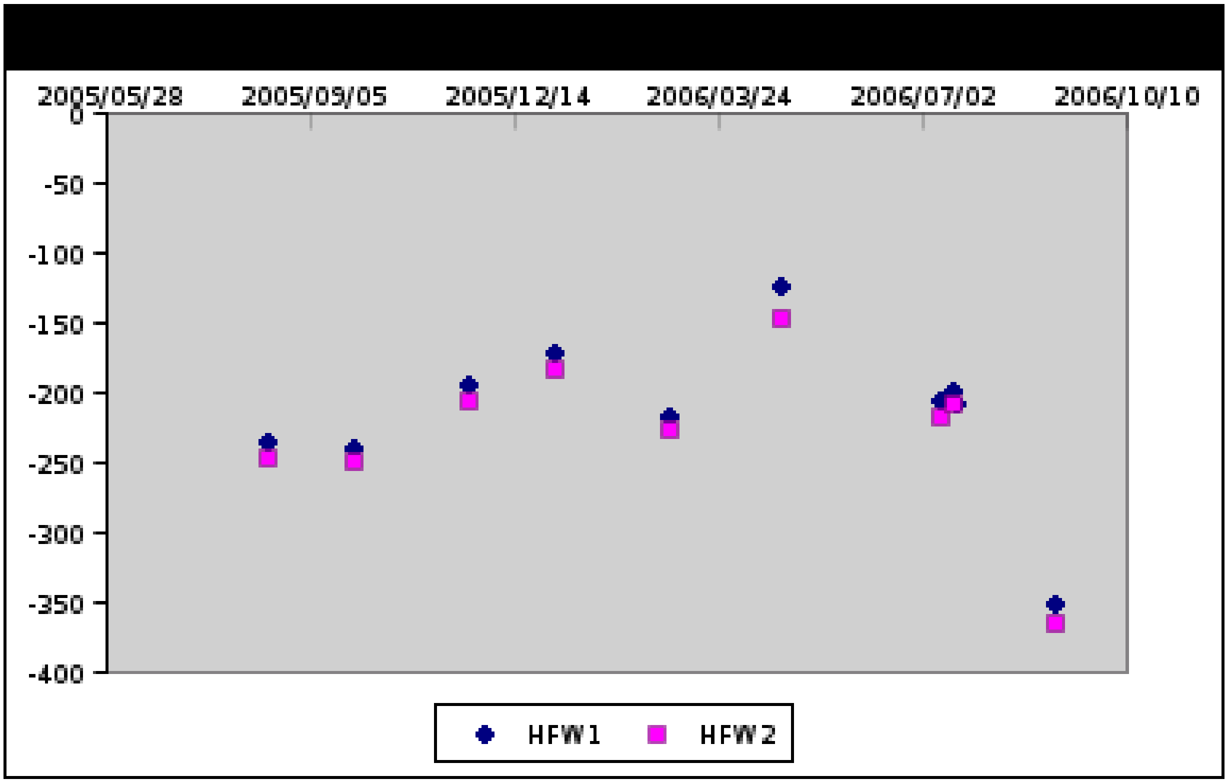

Figure 8: Example of Time Series of Water Levels in Adjacent Wells at Different Depths

5. Conclusions

This project intended to provide the Cannonsville Basin's first broad reconnaissance sampling of groundwater near streams and downgradient from a variety of terrain and land use types. It succeeded in providing a reasonable start. When its data are combined with a parallel project at the "Lowland Farm" in Trout Creek, and baseflow stream sampling, ongoing basin modeling work should be enriched.

The project did not seek to confirm that phosphorus passes via groundwater through streambeds into the water column; that would have required much more expensive work in intimate connection with stream channels. However the work appears to give good evidence that shallow groundwater does convey phosphorus toward streams in various settings in the basin.

TDP concentrations downgradient from subsurface and on-surface phosphorus sources, within 10-500 meters from discharging into surface waters, are at least as high as necessary to account for calibrated "groundwater" values in the 20-30 µg/L range in basin simulation models (Tolson and Shoemaker, 2004; New York City DEP, 2001).

Were the groundwater almost everywhere phosphorus free, management attention could have shifted away from this path and an alternate hypothesis for the appearance of phosphorus in baseflow could be considered most plausible: release of dissolved P from P-enriched sediment deposited within stream channels. That could certainly be happening, in addition to phosphorus conveyance via discharging groundwater. The two phosphorus pathways require different management tactics -- for control of the groundwater path one must attend to what WAP calls the "source barrier", i.e. keep phosphorus from ever being introduced into soil rather than relying on soil to hold it back. DCAP pursues this through precision feeding and other nutrient management tactics that reduce phosphorus brought into farms. An analogous example for residential areas would be low-P dishwasher detergent, compared to conventional 5-6% phosphorus by weight, and another zero-P lawn fertilizer versus fertilizer with conventional P levels. For sediment P control, the source barrier is again relevant since it would reduce concentrations of P in eroded soil. Erosion control tactics are relevant, and a field edge barrier (such as a riparian buffer) that traps sediment before it reaches a water course could ultimately be most important. There is no corresponding "field edge" barrier for dissolved phosphorus carried by groundwater.

Regarding differences between different land uses, the project did not have enough duration or sites to quantify these, and did not expect to do more than point a direction. In general, however, phosphorus concentrations appeared to be correlated with *a priori* phosphorus source strengths of different land cover types. The *a priori* ranking was based on prior basin modeling, septic system investigation, and surface water monitoring work by DEC, WRI, and SWCD. There was one exception: the active dairy farm.

At the active dairy farm in uplands, ground water TDP concentrations were lower than baseflow stream sampling, and mass balance considerations would have suggested higher values. This could be due to the sampling approach. Phosphorus concentrations at 4-8 week intervals in very shallow wells may not have been representative of the actual median concentrations, and many have been biased low. A more likely explanation involves P-sorption kinetics. Research on a wide variety of sands and soils in NY State by Tofflemire and Chen (1977) showed that soils developed in acid glacial till parent materials are more effective in P sorption than are gravelly “outwash” soils, and in most soils the B horizon is more effective than is the C horizon. Greater amounts of iron and aluminum, and silt + clay content were positively correlated with greater P-sorption. In our upland site, all wells (RFW1-RFW5), were screened in the B horizon—the upper subsoil just above the fragipan (or Bx) horizon—in order to intercept the perched water table. Tofflemire and Chen’s research implies that this would be one of the greatest P-sorption zones in all soils, which could explain low values of TDP in upland ground water samples. By contrast, wells at the lowland sites were screened in substratum layers, below the C horizon.

Hamlets with small lots and septic system yield the highest phosphorus values, perhaps higher than expected. Concentrations of most monitored parameters have a very high variability between nearby wells which reflects the discontinuous extent of individual septic system plumes. Extended sampling of these areas is recommended.

Acknowledgments

The principals for this task were Keith S. Porter of the New York State Water Resources Institute (NYS WRI) at Cornell University and Larry Day of the Delaware County Soil and Water Conservation District (SWCD). Also involved have been: co-principal Jery Stedinger of Cornell Civil and Environmental Engineering; staff Steven Pacenka and Dean Hively of NYS WRI; and staff Joseph Miller of SWCD. Hively left for a job with USDA-ARS in Maryland in early March, 2005, after organizing the project's field aspects. Miller, who graduated from SUNY Oneonta during the project, joined as a SWCD intern during May 2005, left for a one-month project in Alaska, worked full time in July and half of August 2005, and remained as a partner in sampling and field laboratory work through the end of field work in September 2006. Kevin Youngers of SWCD assisted in the field in one sampling round.

The project principals and staff are very grateful to the land owners at the H Farm, R Farm, Hamden, and Shaw Road sites, to mayor Ed Snow of the Village of Walton, and to supervisor Perry Shelton of the Town of Tompkins for permission to sample and install wells (except at Shaw Road) at their sites. Ron van Valkenburg, Highway Superintendent of the Town of Tompkins, advised about well locations within the Trout Creek site.

Barb, Jim, Richard, Holley, and Bruce deserve extra thanks in general.

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Kelly Blakeslee of the Delaware County Department of Watershed Affairs and Linda Brainard of Cornell Office of Sponsored Programs provided contracting assistance. Cornell WRI affiliates Diane Cross and Pat Garrett provided contracting and accounting help, as did Peggy Pilch of SWCD. George Barrera of Cornell arranged major purchase orders with laboratories and the contract well driller.

Technical advisors included but were not limited to:

- Pat Bishop, Jeff Lojpersberger, and Victoria Pretti of NYS DEC;
- Beth Boyer, formerly of the SUNY College of Environmental Science and Forestry at Syracuse, NY, and currently of the University of California at Berkeley;
- Bob Schindelbeck of Cornell Crop and Soil Sciences;
- Brian Richards, Tammo Steenhuis, and Larry Geohring of Cornell Biological and Environmental Engineering;
- Tom Butler of Cornell and the Institute for Ecosystem Studies at Millbrook NY; and
- Mike Rafferty of NYS WRI.

Jennifer Aicher of the Upstate Freshwater Institute and Mario Montesedoca of Syracuse University's Center for Environmental Systems Engineering supervised analytical laboratory services and advised about sample shipping and handling.

Bob Schindelbeck was especially helpful in providing lab space for cleaning and storage space for apparatus and supplies. He maintained and loaned a power auger trailer ("Giddings probe") that was used to install one well at G Farm. His lab provided almost all of the deionized water used in the project.

Francisco Flores-Lopez of Cornell Biological and Environmental Engineering carried out a parallel project at the Lowland Farm and analyzed some DCAP project samples for soluble reactive phosphorus to help in integrating the Lowland Farm data with the DCAP project data.

The Delaware County Planning Department loaned the YSI field meter.

Julian Drelich (JD) of USDA NRCS in Walton assisted in finding sites, including introducing project managers to the Hamden site owner.

Bob Howarth of Cornell provided secure storage space for nitric acid between sampling periods.

Project staff responsibilities were:

- Basic project design: Porter, Stedinger, Pacenka, Day
- Site selection: Day, Pacenka, Hively
- Field and field lab techniques: Hively, Pacenka, Day (Boyer, Geohring, Bishop, and Lojpersberger advising)
- Well installation: Day, Hively, Pacenka (and contractor GeoLogic)
- Water and soil sampling: Pacenka, Miller, Hively, Day
- Field lab operation: Pacenka, Miller, Hively (coordination and supplies sharing with Lojpersberger)
- Data management: Pacenka
- Quality assurance: Pacenka (split samples with Bishop for NYS DOH and Severn-Trent; split samples with Flores-Lopez)
- Laboratory selection: Hively
- Quarterly reports and contracting: Pacenka, Day, Stedinger, Blakeslee, Brainard

References

Bishop, P. L., M. R. Rafferty, and J. L. Lojpersberger. 2003. Event-Based Water Quality Monitoring to Determine Effectiveness of Agricultural BMPs. **Proceedings, AWRA 2003 International Congress: "Watershed Management for Water Supply Systems,"** New York City, June 29-July 2, 2003.

Bishop, P. L. and J. L. Lojpersberger. 2004-2006. Personal communications about field and field lab procedures.

Bishop, P. L., W. D. Hively, J. R. Stedinger, J. A. Bloomfield, M. R. Rafferty, and J. L. Lojpersberger. 2005. Multivariate analysis of paired watershed data to evaluate agricultural BMP effects on stream water phosphorus. **Journal of Environmental Quality** 34(3): 1087-1101.

Bishop, P. L., M. R. Rafferty, and J. L. Lojpersberger. 2005. Unpublished data about water quality in R Farm and Shaw Road streams. New York State Department of Environmental Conservation, Albany, NY.

Delaware County Board of Supervisors. Fall 1999. **Delaware County Comprehensive Strategy for Phosphorus Reductions.** Delhi, NY.

Delaware County Board of Supervisors. May 2002. **Delaware County Action Plan: DCAP II: for Watershed Protection and Economic Vitality.** Delhi, NY. Available from URL: <http://www.co.delaware.ny.us/depts/h2o/dcap.htm>.

Fetter, C.W. 1988. **Applied Hydrogeology.** Merrill publishers, Columbus, OH. p. 354.

Geohring, L., O. V. McHugh, M. T. Walter, T. S. Steenhuis, M. S. Akhtar, and M. F. Walter. 2001. *Phosphorus transport into subsurface drains by macropores after manure applications: implications for best management practices.*. **Soil Science**. 166. 12. 896-909.

Hively, W. D., R. B. Bryant, and T. J. Fahey. 2003. Characterization of Runoff from Nine Locations on a Catskills Dairy Farm. **Proceedings, AWRA 2003 International Congress: "Watershed Management for Water Supply Systems,"** New York City, June 29-July 2, 2003.

Hively, W. D. and J. R. Stedinger. 2003. Multivariate analysis of event-based nutrient loading from paired watersheds. **Proceedings, AWRA 2003 International Congress: "Watershed Management for Water Supply Systems,"** New York City, June 29-July 2, 2003.

Hively, W. D. 2004. **Phosphorus loading from a monitored dairy farm landscape**. PhD dissertation, Cornell University, Ithaca, NY.

Mosteller, F., and J. W. Tukey. 1977. **Data Analysis and Regression.** Addison-Wesley, Reading, MA. 588 pp.

New York City Department of Environmental Protection (NYC DEP). December 2001. **New York City's 2001 Watershed Protection Program Summary, Assessment, and Long Term Plan.** New York, NY. 635 pp.

NYS Water Resources Institute (NYS WRI). July 2002b. **Forest Soil Sampling at DEC Research Sites.** DCAP Background Paper 8. Cornell University, Ithaca, NY. 18pp.

NYS Water Resources Institute. 2005a. **Analysis and Explanation of the R. Farm and its Control Site: Integrated monitoring, modeling and assessment at the sub-field, field, and farm scale: Follow-up, 2003-2005: Quality Assurance Project Plan Supplement for shallow groundwater (tasks 1 and 5).** Cornell University, Ithaca, NY.

NYS Water Resources Institute. 2005b. **Systematic Monitoring, Modeling, and Evaluation for Management in the Cannonsville Reservoir Basin: SDWA2002 Tasks: Groundwater Phase I: Quality Assurance Project Plan.** Cornell University, Ithaca, NY.

NYS Water Resources Institute. 2005c. **Analysis and Explanation of the R. Farm and its Control Site: Integrated monitoring, modeling and assessment at the sub-field, field, and farm scale: Follow-up Project Activities: Cumulative Report on Follow-Up Project.** Cornell University, Ithaca, NY.

NYS Water Resources Institute. 2005d. **Systematic Monitoring, Modeling, and Evaluation for Management in the Cannonsville Reservoir Basin: SDWA2002 Tasks: Groundwater. Quality Assurance Project Plan.** Cornell University, Ithaca, NY.

NYS Water Resources Institute. 2005e. **Systematic Monitoring, Modeling, and Evaluation for Management in the Cannonsville Reservoir Basin: Quality Assurance Project Plans: Standard Operating Procedures Appendix.** Cornell University, Ithaca, NY. (common to NYSWRI 2005b and 2005d)

Scott, C. A., M. F. Walter, G N. Nagle, M.T. Walter, N. V. Sierra, and E. S. Brooks. 1991. Residual phosphorus in runoff from successional forest on abandoned agricultural land.: 1. Biogeochemical and hydrological processes. **Biogeochemistry**, 55: 293-309.

Scott, C.A. 1998. **The Hydrology of Phosphorus Transport in Watersheds of Mixed Agricultural and Forest Land Use**. Ph.D. Thesis, Cornell University, Department of Agricultural and Biological Engineering. Ithaca, NY.

Soren, J. 1963. **The Ground-Water Resources of Delaware County, New York.** Bulletin GW-50. USGS, Albany. 59pp.

Tofflemire, T.J. and M. Chen. 1977. Phosphate removal by sands and soils. **Ground Water,** 15:377-387.

Tolson, B. A. and Shoemaker, C. A. 2004. **Watershed modeling of the Cannonsville Basin using SWAT2000: Model development, calibration and validation for the prediction of flow, sediment and phosphorus transport to the Cannonsville Reservoir. Version 1.0.** Technical Report, School of Civil and Environmental Engineering, Cornell University. 159 pp. http://techreports.library.cornell.edu:8081/Dienst/UI/1.0/Display/cul.wat/2004-2.

Velleman, P. F. and D. C. Hoaglin. 1981. **Applications, Basics, and Computing of Exploratory Data Analysis.** Duxbury Press, Boston, MA. 354 pp.

Appendix A: Example Logs for Commercial Wells

GeoLogic NY, Inc.

P.O. Box 350
Homer, NY 13077
607-749-5000
607-749-5063 (fax)

SUBSURFACE LOG

Boring No.: MW-3
Project No.: 205009A-D
Date Started: 05/06/05
Date Completed: 05/06/05
Reference Elevation: N/A

Project: Delaware County Soil and Water Conservation
Location: Hamden, New York

Depth (ft)	Sample Number	SPT Blows (6")	N-Value	Recovery (ft.)	MATERIAL DESCRIPTION	Well Installation	Remarks
0–2	1	2 2 3 4	5	1.1	Brown fine-coarse SILT, Some fine Sand, moist		Stickup Guard Pipe Portland Cement
2–4	2	4 4 2 4	6	1.1	similar		
4–6	3	6 12 10 10	22	1.3	Brown fine-coarse SAND and GRAVEL, little silt, moist		Auger Cuttings 0' - 10.0'
6–8	4	6 11 14 17	25	1.2	similar, saturated		2" Dia. PVC Riser, +3.0' - 13.0'
8–10	5	11 11 11 9	22	1.0	similar		
10–12	6	5 4 4 4	8	1.5	Brown fine-medium SAND, saturated Brown fine-coarse SAND and GRAVEL, little silt, saturated		Bentonite Seal 10.0' - 11.0'
12–14	7	6 10 11 14	21	0.9	Brown fine-coarse SAND, Some fine-coarse Gravel, little silt, saturated		#1 Sandpack 11.0' - 16.0'
14–16	8	11 18 17 17	35	1.2	similar		2" Dia. PVC Well Screen, 0.020 Slot, 13.0' - 16.0'
16–18	9	12 13 11 14	24	1.0	Brown fine-coarse SAND and GRAVEL, little silt, saturated		**Note: Driller visual classification only. Samples retained by Client. Classification subject to change upon review of samples by experienced professional.**
18–20	10	12 11 11 18	22	2.0	similar, saturated		
20–21					End of Borehole		Upon completion, water level at 5.0'.

Sampling Method: ASTM D-1586
Notes: 4 1/4" ID Hollow Stem Augers

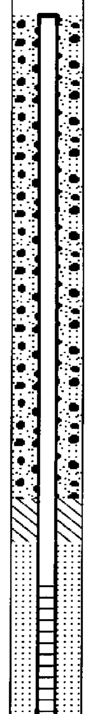
Visually Classified by: Driller
File: 205009A-D/tech/MW-3

GeoLogic NY, Inc.
P.O. Box 350
Homer, NY 13077
607-749-5000
607-749-5063 (fax)

SUBSURFACE LOG

Boring No.: B-1
Project No.: 205009B-D
Date Started: 08/04/05
Date Completed: 08/04/05
Reference Elevation: N/A

Project: Cornell University / Delaware County SWCD
Location: "H" Farm, Walton, New York

Depth (ft)	Sample Number	Sample SPT Blows (6")	Sample N-Value	Recovery (ft.)	MATERIAL DESCRIPTION	Well Installation	Remarks
0–2	1	1 2 3 10	5	0.9	Topsoil Brown SILT and coarse-fine SAND, little gravel, damp		Stickup at surface
2–4	2	12 10 11 10	21	1.1	Brown coarse-fine SAND and GRAVEL, Some Silt, damp		
4–6	3	9 11 15 18	26	1.3	similar, cobbles, wet		Backfill Cuttings 0' - 11.0'
6–8	4	5 9 8 16	17	0.8	similar, saturated		2" Dia. PVC Riser, 0' - 13.0'
8–10	5	16 22 26 31	48	1.0	Brown coarse-fine SAND, GRAVEL and SILT, occasional cobbles, wet		
10–12	6	5 2 30 62	32	1.0	similar		Bentonite Seal 11.0' - 12.0'
12–14	7	6 10 14 15	24	1.0	similar		#1 Sandpack 12.0' - 16.0'
14–16	8	7 8 10 10	18	1.0	similar, saturated		2" Dia. PVC Well Screen, 0.020 Slot, 13.0' - 16.0'
16–20					End of Borehole		With augers at 15.0', water level at 8.5'. Introduced 50 gallons of water for flushing.

Sampling Method: ASTM D-1586
Notes: 4 1/4" ID Hollow Stem Augers
Visually Classified by: Driller / S. Cummins
File: 205009B-D/tech/B-1

GeoLogic NY, Inc. **P.O. Box 350** **Homer, New York 13077** **(607) 749-5000** Project: Location:	**KEY TO** **SUBSURFACE LOG**	Boring No.: B-1 Project No.: 200001 Date Started: 1/31/05 Date Completed: 1/31/05 Sheet 1 of 1 Reference Elevation: 100.0

Depth (ft.)	Sample No.	Type	SPT Blows	N-Value	Recovery (ft.)	PID Reading (ppm)	MATERIAL DESCRIPTION	REMARKS
0							Ground Surface	Water level at 2.0' with augers at 7.5'.
1	1	ss	1 2 2 1	4	2.0	32	Brown SILT, Some fine-coarse Sand, trace clay, moist-loose	At completion water level at 2.2' with augers at 10.0'.
2	2						Gray SHALE, medium hard weathered, thin bedded, some fractures	Run #1: 3.0'-5.0' 95% Recovery, 50% RQD

1 2 3 4 5 6 7 8 9 10

TABLE I

Identification of soil type is made on basis of an estimate of particle sizes, and in the case of fine-grained soils also on basis of plasticity.

Soil Type		Soil Particle	
Boulder		> 12"	
Cobble		12" - 3"	
Gravel	- Coarse	3" - 3/4"	Coarse Grained
	- Fine	3/4" - #4	(Granular)
Sand	- Coarse	#4 - #10	
	- Medium	#10 - #40	
	- Fine	#40 - #200	
Silt-Non Plastic (Granular)		< #200	Fine Grained
Clay-Plastic (Cohesive)			

TABLE II

The following terms are used in classifying soils consisting of mixtures of two or more soil types. The estimate is based on weight of total sample.

Term	Percent of Total Sample
"and"	35 - 50
"some"	20 - 35
"little"	10 - 20
"trace"	1 - 10

(When sampling gravelly soils with a standard split spoon, the true percentage of gravel is often not recovered due to the relatively small sampler diameter.)

TABLE III

The relative compactness or consistency is described in accordance with the following terms.

Granular Soils Term	Blows per Foot, N	Cohesive Soils Term	Blows per Foot, N
Loose	< 11	Very Soft	< 2
Firm	11 - 30	Soft	2 - 4
Compact	31 - 50	Medium	4 - 8
Very Compact	> 51	Stiff	8 - 15
		Very Stiff	15 - 30
		Hard	>30

(Large particles in the soils will often significantly influence the blows per foot recorded during the Penetration Test.)

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TABLE IV

Stratified Soils

Descriptive Term	Thickness
Parting	- 0" - 1/16"
Seam	- 1/16" - 1/2"
Layer	- 1/2" - 12"
Stratum	- >12"
Varved Clay	- Alternating seams or layers of sand, silt & clay
Pocket	- small, erratic deposit, usually <12"
Lens	- lenticular deposit
Occasional	- one or less per foot of thickness
Frequent	- more than one per foot of thickness

TABLE V

Rock Classification Terms			
Term		Meaning	
Hardness	Soft	Scratched by fingernail	
	Medium Hard	Scratched easily by penknife	
	Hard	Scratched with difficulty by penknife	
	Very Hard	Cannot be scratched by penknife	
Weathering	Very Weathered	Judged from the relative amounts of disintegration,	
	Weathered	iron staining, core recovery, clay seams, etc.	
	Sound		
Bedding	Laminated	Natural breaks in Rock Layers	<1"
	Thin bedded		1"-4"
	Bedded		4"-12"
	Thick bedded		12"-36"
	Massive		>36"
(Fracturing refers to natural breaks in the rock oriented at some angle to the rock layers.)			

GENERAL INFORMATION & KEY TO SUBSURFACE LOGS

The information presented in the following defines some of the procedures and terms used on the Subsurface Logs to describe the conditions encountered.

1. The figures in the Depth column defines the scale of the Subsurface Log.
2. The Sample No. is used for identification on sample containers.
3. The sample column shows, graphically, the depth range from which a sample was recovered. (ss – split spoon; core – rock core; st – shelby tube; dp – direct push).
4. Blows on Sampler - shows the results of the "Penetration Test", recording the number of blows required to drive a split spoon sampler into the soil. The number of blows required for each six inches of penetration is recorded. The first 6 inches of penetration is considered to be a seating drive. The number of blows required for the second and third 6 inches of penetration is termed the penetration resistance, N. The outside diameter of the sampler, the hammer weight and the length of drop are noted at the bottom of the Subsurface Log.
5. Recovery shows the length of the recovered soil sample for the sample device noted.
6. All recovered soil samples are reviewed in the office by an experienced technical specialist or geologist, unless noted otherwise. The visual descriptions are made on the basis of a combination of the field descriptions and observations and the sample as received in the office. The method of visual classification is based primarily on the Unified Soil Classification (ASTM D 2487-83) with regard to the particle size and plasticity. (See Table I). Additionally, the relative portion, by weight, of two or more soil types is described for granular soils in accordance with "Suggested Methods of Test for Identification of Soils" by D.M. Burmister, ASTM Special Technical Publication 479, June 1970. (See Table II) The description of the relative soil density or consistency is based upon the penetration records as defined on Table No. III. The description of the soil moisture is based upon the relative wetness of the soil as recovered and is described as damp, moist, wet and saturated. Water introduced in the boring either naturally or during drilling may have affected the moisture condition of the recovered sample. Special terms are used as required to describe materials in greater detail; several such terms are listed in Table IV. When sampling gravelly soils with a standard two-inch diameter split spoon, the true percentage of gravel is often not recovered due to the relatively small sampler diameter. The presence of boulders and large gravel is sometimes, but not necessarily, detected by an evaluation of the casing/hollow stem augers and samplers blows or through the "action" of the drill rig.
7. The description of the rock shown is based on the recovered rock core and the field observations. The terms frequently used in the description are included in Table V.
8. The stratification lines represent the approximate boundary between soil types, and the actual transition may be gradual.
9. Miscellaneous observations and procedures noted in the field are shown in this column, including water level observations. It is important to realize the reliability of the water level observations depends upon the soil type (water does not readily stabilize in a hole through fine grained soils), and that drill water used to advance the boring may have influenced the observations. The groundwater level typically will fluctuate seasonally. One or more perched or trapped water levels may exist in the ground seasonally. All the available readings should be evaluated. If definite conclusions cannot be made, it is often prudent to examine the conditions more thoroughly through test pit excavations or monitoring wells.
10. The length of core run is defined as the length of penetration of the core barrel. Core recovery is the length of core recovered divided by the core run. The RQD (Rock Quality Designation) is the total pieces of NX core exceeding 4 inches in length divided by the core run. The size of the core barrel used is also noted at the bottom of the subsurface log.

The Subsurface Logs attached to this report present the observations and mechanical data collected at the site, supplemented by classification of material removed from the borings as determined through visual identification. It is cautioned that the materials removed from the borings represent only a fraction of the total volume of the deposits at the site and may not necessarily be representative of the subsurface conditions between adjacent borings or between the sampled intervals. The data presented on the Subsurface Logs together with the recovered samples will provide a basis for evaluating the character of the subsurface conditions relative to the project. The evaluation must consider all the recorded details and their significance relative to each other. Often analyses of boring data indicate the need for additional testing or sampling procedures to more accurately evaluate the subsurface conditions. Any evaluation of the contents of this report and the recovered samples must be performed by knowledgeable Professionals.

Appendix B: Data Details

This appendix provides summary statistics for most time series of sampling results at a site or "blank" location. A few lesser locations and parameters are omitted. Three preliminary tables define the codings used in the statistics, and a fourth table contains the statistics themselves.

Site Codes:

SRS1	Shaw Road stream at DEC station (unnamed)
RFS1	R Farm stream, at DEC station (tributary of Wright Brook)
SRS2	Shaw Road spring
HFS2	H Farm spring
RFW2	R Farm well #2
WW1	Walton Village well #1
WW2	Walton Village well #2
HFW1	H Farm well #1
HFW2	H Farm well #2
RFW1	R Farm well #1
RFW3	R Farm well #3
RFW4	R Farm well #4
RFW5	R Farm well #5
RFT1	R Farm tile drain near well #1
GFW1	G Farm well #1
GFW2	G Farm well #2
GFW3	G Farm well #3
TCW1	Trout Creek well #1
TCW2	Trout Creek well #2
HFS1	H Farm stream (Feak Hollow Brook)
RFS2	R Farm stream, above pond
TCS1	Trout Creek stream, Trout Creek
WS1	Walton Village Stream, Middle Brook
HFFB	H Farm field blank - taken with peristaltic pump, equivalent to all other field blanks except RFFB
RFFB	R Farm field blank - taken with suction pump; distinct from other field blanks
GFFB	G Farm field blank - taken with peristaltic pump, equivalent to all other field blanks except RFFB
WFB	Walton Village field blank - taken with peristaltic pump, equivalent to all other field blanks except RFFB
ILBF	Ithaca Lab blank, filtered - made with deionized water from Cornell
ILBU	Ithaca Lab blank, unfiltered - made with deionized water from Cornell

Parameters:

Parameter	Analyst	Definition	Units
TDP	UFI	Total Dissolved Phosphorus	micrograms/liter
NO3-N	SUESE	Nitrate as nitrogen	micrograms/liter
FieldSpCond	WRI/SWCD	Specific conductance measured in field	micro-Siemens/centimeter
Na	SUESE	Sodium	micrograms/liter
Ca	SUESE	Calcium	micrograms/liter
Mg	SUESE	Magnesium	micrograms/liter
Cl	SUESE	Chloride	micrograms/liter
SO4	SUESE	Sulfate (as sulfate)	micrograms/liter

The statistics are exploratory data analysis (EDA) statistics (Velleman and Hoaglin, 1981; Mosteller and Tukey, 1977) that represent a group of data robustly in the presence of error. The median of a time series is a measure of central tendency of the data, similar to an average but unaffected by a few odd values. Half of the data points are within the range between the lower and upper "fourths" (similar to quartiles, and also called "hinges"). The difference between the fourths, termed the "half spread", is a measure of data range similar to a standard deviation except not much affected by a few way out values. Lower and upper "fences" delimiting suspected and probable outliers are defined at the fourth plus or minus 1.5 and 3.0 times the half spread. There are sufficient data in every series to estimate a median -- only a single value is needed. Fourths require more points to estimate well, a theoretical minimum is three points and it is much better to have five or seven points. Outlier fences are defined in terms of the half spread, which encompasses all data ; are defined, there can't be any outliers unless there are at least three data points.

Six statistics from LOOUFEN through UPOUFEN (defined below) provide something like a histogram of the data. Many people have seen "boxplots" based on these values which are also from the EDA genre. A boxplot may also display individual outliers outside the inner fences.

Headings:

PARAM-SITE	Parameter - sampling site
N	Count of samples with usable data for this parameter
LOOUFEN	Cutoff of probable low outliers (probable low outliers are less than LOOUFEN)
LOINFEN	Cutoff of suspected low outliers (suspected low outliers are equal to or greater than LOOUFEN and less than LOINFEN)
LO4TH	lower fourth (similar to 25th quartile)
MEDIAN	median
UP4TH	upper fourth (similar to 75th quartile)
UPINFEN	Cutoff of suspected high outliers (suspected high outliers are greater than UPINFEN and less than or equal to UPOUFEN)
UPOUFEN	Cutoff of probable high outliers (probably high outliers are greater than UPOUFEN)

Statistics:

PARAM-SITE	N	LOOUFEN	LOINFEN	LO4TH	MEDIAN	UP4TH	UPINFEN	UPOUFEN
TDP-SRS1	2	4.400	4.400	4.400	7.750	11.100	11.100	11.100
TDP-RFS1	12	11.500	11.500	25.150	38.950	52.650	59.100	160.400
TDP-SRS2	2	1.400	1.400	1.400	8.250	15.100	15.100	15.100
TDP-HFS2	7	16.200	16.200	16.250	17.200	18.200	20.800	20.800
TDP-RFW2	9	6.200	6.200	16.000	18.000	27.300	36.600	36.600
TDP-WW1	6	27.400	27.400	28.100	29.650	36.300	38.600	38.600
TDP-WW2	6	26.500	26.500	27.300	30.450	38.300	38.300	38.300
TDP-HFW1	7	41.000	41.000	45.550	48.000	57.800	62.000	62.000
TDP-HFW2	7	39.400	39.400	44.250	48.600	72.800	94.400	170.100
TDP-RFW1	10	3.800	3.800	5.300	7.550	11.800	13.600	28.600
TDP-RFW3	10	3.400	3.400	8.500	12.250	15.400	25.500	25.500
TDP-RFW4	11	8.100	8.100	10.600	18.700	26.950	49.500	49.500
TDP-RFW5	9	6.800	6.800	9.800	11.800	13.800	18.500	21.300
TDP-RFT1	8	17.400	17.400	34.350	49.850	106.250	155.900	155.900
TDP-GFW1	9	3.500	3.500	5.200	9.100	11.100	13.700	162.640
TDP-GFW2	9	70.000	70.000	91.100	96.500	147.300	176.500	176.500
TDP-GFW3	9	32.200	32.200	42.400	63.400	69.300	87.100	87.100
TDP-TCW1	6	11.900	11.900	22.300	28.650	33.300	38.600	38.600
TDP-TCW2	6	18.900	18.900	61.200	82.800	104.200	107.800	107.800
TDP-HFS1	7	3.700	3.700	4.850	5.200	12.200	22.200	22.200
TDP-RFS2	9	2.500	2.500	4.700	8.300	9.100	12.100	23.900
TDP-TCS1	6	5.000	5.000	7.800	10.400	14.000	14.000	23.500
TDP-WS1	6	3.700	3.700	7.800	10.400	14.900	14.900	45.600
TDP-HFFB	1	0.700	0.700	0.700	0.700	0.700	0.700	0.700
TDP-RFFB	9	0.200	0.200	0.200	1.400	1.800	3.800	3.800
TDP-GFFB	4	0.600	0.600	0.900	1.700	3.200	4.200	4.200
TDP-WFB	5	0.200	0.200	0.200	0.200	1.100	1.500	1.500
TDP-ILBF	10	0.600	0.600	0.700	1.300	1.900	2.200	2.200
TDP-ILBU	2	0.700	0.700	0.700	1.100	1.500	1.500	1.500
NO3-N-SRS1	2	15.318	15.318	15.318	36.359	57.400	57.400	57.400
NO3-N-RFS1	11	130.600	130.600	223.608	501.146	580.001	847.060	1674.300
NO3-N-SRS2	2	158.914	158.914	158.914	257.357	355.800	355.800	355.800
NO3-N-HFS2	7	119.672	119.672	149.874	188.795	223.114	266.936	266.936
NO3-N-RFW2	9	606.000	606.000	664.582	781.714	892.282	1160.368	1332.286
NO3-N-WW1	6	4582.873	4582.873	4582.873	4754.168	5086.312	5086.312	6007.453
NO3-N-WW2	6	4601.515	4601.515	4601.515	4929.120	5157.487	5157.487	6165.751
NO3-N-HFW1	7	82.076	82.076	357.306	950.727	1218.643	1424.552	1424.552

PARAM-SITE	N	LOOUFEN	LOINFEN	LO4TH	MEDIAN	UP4TH	UPINFEN	UPOUFEN
NO3-N-HFW2	7	218.361	218.361	405.093	784.000	1087.422	1153.825	1153.825
NO3-N-RFW1	9	6.672	6.672	13.206	42.800	156.730	363.583	1608.375
NO3-N-RFW3	10	161.732	161.732	450.189	1412.850	1554.969	2149.000	2149.000
NO3-N-RFW4	11	3.700	3.700	5.148	34.500	66.597	148.500	148.500
NO3-N-RFW5	8	2.154	2.154	4.440	58.215	769.190	1285.914	2168.700
NO3-N-RFT1	8	1086.400	1086.400	1277.533	1354.831	2386.504	3577.344	3577.344
NO3-N-GFW1	9	618.400	618.400	1148.400	1800.600	2772.235	4925.917	4925.917
NO3-N-GFW2	9	1373.480	1373.480	1732.867	2318.179	4662.732	8101.100	8101.100
NO3-N-GFW3	9	1969.648	1969.648	4191.510	5180.295	7291.894	11882.800	11882.800
NO3-N-TCW1	6	2843.000	2843.000	3101.633	3388.026	4142.418	5518.703	5518.703
NO3-N-TCW2	5	7384.000	7384.000	7693.831	8780.710	10756.856	11926.879	11926.879
NO3-N-HFS1	7	28.000	28.000	98.063	156.787	179.030	192.029	192.029
NO3-N-RFS2	8	9.138	9.138	151.816	287.606	357.448	636.872	636.872
NO3-N-TCS1	6	153.422	153.422	274.000	299.683	369.214	405.819	405.819
NO3-N-WS1	6	242.048	242.048	414.736	590.890	644.644	814.309	814.309
NO3-N-HFFB	1	51.546	51.546	51.546	51.546	51.546	51.546	51.546
NO3-N-RFFB	9	9.889	9.889	103.924	140.500	187.005	218.100	218.100
NO3-N-GFFB	4	139.600	139.600	167.100	201.950	212.850	216.400	216.400
NO3-N-WFB	5	9.325	9.325	43.797	107.877	121.449	226.323	226.323
NO3-N-ILBF	10	10.306	10.306	51.594	93.822	205.200	209.779	209.779
NO3-N-ILBU	6	44.588	44.588	77.992	97.083	202.900	208.712	208.712
FieldSpCond-SRS1	2	30.600	30.600	30.600	41.100	51.600	51.600	51.600
FieldSpCond-RFS1	12	49.200	49.200	69.300	90.250	99.350	125.600	229.200
FieldSpCond-SRS2	2	52.900	52.900	52.900	58.000	63.100	63.100	63.100
FieldSpCond-HFS2	7	34.000	34.000	37.950	39.400	48.600	54.800	89.300
FieldSpCond-RFW2	9	56.100	56.100	67.200	71.100	76.500	86.800	86.800
FieldSpCond-WW1	7	830.000	830.000	863.500	908.000	931.000	958.000	958.000
FieldSpCond-WW2	7	222.300	801.000	842.500	912.000	1157.000	1251.000	1251.000
FieldSpCond-HFW1	9	121.400	344.200	344.200	433.000	440.400	469.900	469.900
FieldSpCond-HFW2	8	169.700	169.700	289.300	405.300	451.100	496.500	496.500
FieldSpCond-RFW1	11	43.800	67.300	103.000	112.000	134.300	151.700	231.100
FieldSpCond-RFW3	13	61.600	93.400	94.600	96.100	105.700	110.300	211.200
FieldSpCond-RFW4	12	181.800	181.800	208.750	232.200	318.050	389.600	389.600
FieldSpCond-RFW5	9	57.000	57.000	82.600	135.700	301.800	425.400	425.400
FieldSpCond-RFT1	8	31.000	31.000	43.850	71.850	95.500	134.300	134.300
FieldSpCond-GFW1	10	76.400	76.400	131.300	166.000	206.000	260.300	260.300
FieldSpCond-GFW2	11	124.700	124.700	256.200	359.500	458.150	711.000	767.000
FieldSpCond-GFW3	11	186.500	186.500	319.850	365.700	508.200	606.000	1089.000
FieldSpCond-TCW1	7	383.700	383.700	573.000	669.000	717.500	867.000	867.000
FieldSpCond-TCW2	8	616.000	616.000	634.500	699.000	754.000	798.000	798.000

PARAM-SITE	N	LOOUFEN	LOINFEN	LO4TH	MEDIAN	UP4TH	UPINFEN	UPOUFEN
FieldSpCond-HFS1	5	33.400	33.400	38.900	44.400	58.800	62.200	62.200
FieldSpCond-RFS2	10	27.000	27.000	33.500	39.800	48.000	48.000	104.700
FieldSpCond-TCS1	5	67.900	67.900	71.500	79.000	87.500	87.500	136.100
FieldSpCond-WS1	4	71.400	71.400	76.450	83.450	95.200	105.000	105.000
FieldSpCond-HFFB	1	21.900	21.900	21.900	21.900	21.900	21.900	21.900
FieldSpCond-RFFB	6	8.900	8.900	12.500	14.400	16.900	17.300	17.300
FieldSpCond-GFFB	2	11.600	11.600	11.600	12.900	14.200	14.200	14.200
FieldSpCond-WFB	2	22.700	22.700	22.700	114.850	207.000	207.000	207.000
FieldSpCond-ILBF	7	7.700	7.700	8.700	9.800	31.050	44.800	44.800
FieldSpCond-ILBU	2	7.700	7.700	7.700	26.250	44.800	44.800	44.800
Na-SRS1	2	1310.510	1310.510	1310.510	1330.255	1350.000	1350.000	1350.000
Na-RFS1	12	1702.844	1702.844	1928.740	2219.896	3021.402	3443.480	5772.206
Na-SRS2	2	1040.000	1040.000	1040.000	1188.000	1336.000	1336.000	1336.000
Na-HFS2	7	1250.000	1250.000	1284.033	1457.423	1806.380	2197.063	2197.063
Na-RFW2	9	1947.627	1947.627	2118.474	2136.593	2708.324	3354.929	3354.929
Na-WW1	6	111615.230	111615.230	111615.230	123583.565	128466.660	130000.000	130000.000
Na-WW2	5	120347.230	120347.230	120347.230	133000.000	134976.130	139289.470	139289.470
Na-HFW1	7	17439.423	17439.423	40285.444	50135.597	57500.000	70096.432	70096.432
Na-HFW2	7	26172.026	26172.026	37796.251	48520.474	52520.227	55600.000	55600.000
Na-RFW1	10	2620.000	2620.000	2950.000	3691.872	4808.985	4808.985	37274.327
Na-RFW3	9	2471.617	2471.617	2670.000	2981.831	3190.000	3820.308	3820.308
Na-RFW4	11	4740.000	4740.000	8410.781	16899.037	39286.726	47815.917	47815.917
Na-RFW5	7	4550.000	7631.897	7646.449	8000.000	8954.021	9182.000	23744.000
Na-RFT1	8	2060.000	2060.000	2378.266	2579.877	2782.377	2899.280	3793.000
Na-GFW1	9	8920.000	8920.000	10133.000	11207.963	15521.388	21790.181	21790.181
Na-GFW2	9	14486.639	14486.639	36370.000	50184.100	79450.090	107510.520	166000.000
Na-GFW3	9	20725.036	20725.036	36529.000	46150.000	62261.783	74979.352	103000.000
Na-TCW1	6	42027.130	42027.130	49600.000	80273.673	92792.130	104193.320	104193.320
Na-TCW2	6	64700.000	64700.000	72916.640	80069.574	85980.122	99348.102	99348.102
Na-HFS1	7	1080.804	1080.804	1209.965	1299.101	1871.161	2306.356	2306.356
Na-RFS2	10	1102.000	1102.000	1261.254	1446.840	1559.195	1717.000	1717.000
Na-TCS1	6	5421.669	5421.669	5630.000	6519.035	7894.273	9736.244	9736.244
Na-WS1	6	5574.032	5574.032	6560.000	7044.861	7720.000	7720.000	11409.713
Na-HFFB	1	1819.936	1819.936	1819.936	1819.936	1819.936	1819.936	1819.936
Na-RFFB	8	917.818	917.818	1107.656	1229.756	1371.553	1484.648	1484.648
Na-GFFB	4	1172.499	1172.499	1239.540	1331.194	1443.559	1531.311	1531.311
Na-WFB	5	1027.466	1027.466	1110.000	1179.218	1494.463	1640.000	1640.000
Na-ILBF	10	1082.980	1082.980	1175.350	1353.379	1564.451	1796.000	1796.000
Na-ILBU	6	1082.653	1082.653	1110.000	1315.412	1640.000	1640.000	3743.000

PARAM-SITE	N	LOOUFEN	LOINFEN	LO4TH	MEDIAN	UP4TH	UPINFEN	UPOUFEN
Ca-SRS1	2	4540.000	4540.000	4540.000	4745.000	4950.000	4950.000	4950.000
Ca-RFS1	12	3937.000	3937.000	5787.216	8613.926	9771.715	11866.550	24319.387
Ca-SRS2	2	3967.000	3967.000	3967.000	4308.500	4650.000	4650.000	4650.000
Ca-HFS2	7	2320.403	2320.403	2419.577	2740.000	3102.664	3267.583	5210.537
Ca-RFW2	9	4640.000	4640.000	6859.554	8089.740	10236.936	10942.587	10942.587
Ca-WW1	6	25800.000	25800.000	25800.000	26745.376	28619.268	28952.115	28952.115
Ca-WW2	5	23400.000	23400.000	23400.000	25546.692	27710.577	31074.267	31074.267
Ca-HFW1	7	2793.653	2793.653	6980.209	14400.000	16706.499	17773.045	17773.045
Ca-HFW2	7	3384.787	3384.787	7110.682	12242.409	12944.292	14100.000	14100.000
Ca-RFW1	10	2990.000	2990.000	7466.795	10839.208	11828.763	12700.000	12700.000
Ca-RFW3	9	4650.000	4650.000	7815.458	9714.376	12423.000	13395.292	13395.292
Ca-RFW4	11	12345.675	12345.675	13509.311	14976.292	16756.786	19429.509	27600.000
Ca-RFW5	7	1520.000	1520.000	2367.087	6099.000	13854.940	16000.000	16000.000
Ca-RFT1	8	4139.000	4139.000	6292.500	8056.815	10321.627	12782.447	12782.447
Ca-GFW1	8	6733.197	6733.197	6925.000	11531.548	13272.512	14409.578	14409.578
Ca-GFW2	9	6430.586	6430.586	6837.606	15792.000	21656.411	27800.000	27800.000
Ca-GFW3	9	5248.838	5248.838	11160.104	15000.000	18546.756	24786.803	24786.803
Ca-TCW1	6	17614.258	17614.258	18000.000	27350.395	40322.687	53605.741	53605.741
Ca-TCW2	6	20200.000	20200.000	21100.000	26049.571	31364.211	31364.211	49349.635
Ca-HFS1	7	2006.423	2006.423	2232.334	2498.921	3577.832	5330.263	5330.263
Ca-RFS2	10	2474.000	2474.000	3754.018	5603.405	7949.000	12134.000	12134.000
Ca-TCS1	6	3030.000	3030.000	3215.868	4203.497	4956.110	4956.110	8863.577
Ca-WS1	6	3330.000	3330.000	3965.029	4903.289	6260.000	6260.000	9714.075
Ca-HFFB	1	86.024	86.024	86.024	86.024	86.024	86.024	86.024
Ca-RFFB	8	75.019	75.019	79.151	119.697	152.850	174.139	174.139
Ca-GFFB	4	92.003	92.003	102.469	118.283	144.153	164.674	164.674
Ca-WFB	5	68.370	68.370	70.100	70.491	72.500	72.500	78.569
Ca-ILBF	10	74.100	74.100	79.868	85.738	108.264	117.326	159.963
Ca-ILBU	6	57.106	57.106	62.650	66.850	72.743	73.052	73.052
Mg-SRS1	2	1250.000	1250.000	1250.000	1300.579	1351.158	1351.158	1351.158
Mg-RFS1	12	1008.510	1008.510	1262.170	2002.610	2356.005	2935.244	4675.134
Mg-SRS2	2	677.618	677.618	677.618	697.809	718.000	718.000	718.000
Mg-HFS2	7	1250.000	1250.000	1442.736	1467.750	1959.499	2497.103	2497.103
Mg-RFW2	9	1130.000	1130.000	1737.644	2237.379	2247.528	2620.000	4515.185
Mg-WW1	6	4212.901	4212.901	4212.901	4476.691	4670.000	4910.000	4910.000
Mg-WW2	5	4255.251	4255.251	4255.251	4570.000	4976.079	5574.084	5574.084
Mg-HFW1	7	1117.440	1117.440	2173.427	3750.000	4545.528	4692.436	4692.436
Mg-HFW2	7	1323.778	1323.778	2275.572	2890.000	3602.471	4440.000	4440.000
Mg-RFW1	10	680.000	680.000	1769.242	2026.188	3040.000	3555.615	3555.615
Mg-RFW3	9	1100.000	1362.602	1879.251	2269.506	2390.000	2736.200	2736.200

PARAM-SITE	N	LOOUFEN	LOINFEN	LO4TH	MEDIAN	UP4TH	UPINFEN	UPOUFEN
Mg-RFW4	11	2190.000	2190.000	2961.453	3519.551	4267.092	4685.802	7290.000
Mg-RFW5	7	560.000	560.000	929.567	2945.000	4829.279	6357.228	6357.228
Mg-RFT1	8	919.918	919.918	1431.390	2047.658	3220.610	3680.595	3680.595
Mg-GFW1	9	1920.000	1920.000	2547.855	2926.777	3937.311	4059.136	4059.136
Mg-GFW2	9	1202.854	1202.854	2124.311	3253.550	4399.995	6150.000	6150.000
Mg-GFW3	9	1288.115	2495.601	3091.000	3580.382	3780.000	4340.815	4990.000
Mg-TCW1	6	2767.254	2767.254	3510.000	4751.607	6890.265	11793.917	11793.917
Mg-TCW2	6	4610.000	4610.000	5137.980	5402.644	6241.417	6241.417	11976.274
Mg-HFS1	7	926.000	926.000	1140.481	1260.000	1635.315	2192.596	2192.596
Mg-RFS2	10	605.000	605.000	642.457	827.849	1270.000	2103.798	2103.798
Mg-TCS1	6	1160.000	1160.000	1409.034	1688.749	1989.509	1989.509	3271.845
Mg-WS1	6	1250.000	1250.000	1597.556	1932.588	2300.000	2855.966	2855.966
Mg-HFFB	1	29.733	29.733	29.733	29.733	29.733	29.733	29.733
Mg-RFFB	8	10.905	15.756	17.779	20.404	22.080	24.015	24.015
Mg-GFFB	4	13.048	13.048	14.698	17.258	21.090	24.013	24.013
Mg-WFB	5	8.450	8.450	8.930	18.402	20.717	26.877	26.877
Mg-ILBF	10	10.500	10.500	14.652	23.727	25.899	28.859	28.859
Mg-ILBU	6	7.210	7.210	8.320	14.810	19.830	28.080	28.080
Cl-SRS1	2	263.800	263.800	263.800	425.389	586.979	586.979	586.979
Cl-RFS1	12	1315.000	1315.000	1560.206	2071.481	3413.963	4234.100	11053.159
Cl-SRS2	2	229.581	229.581	229.581	347.640	465.700	465.700	465.700
Cl-HFS2	7	450.000	450.000	487.744	521.059	549.141	568.293	568.293
Cl-RFW2	9	1307.000	1307.000	1579.250	1796.300	1815.155	1974.958	2374.200
Cl-WW1	6	76172.322	76172.322	149883.913	175424.940	218436.771	238114.814	238114.814
Cl-WW2	6	35789.494	165940.538	165940.538	203128.208	227741.418	231827.167	231827.167
Cl-HFW1	7	13185.232	13185.232	49889.922	84381.000	103603.554	118946.215	118946.215
Cl-HFW2	7	22364.665	22364.665	58238.438	75747.020	88772.945	119861.996	119861.996
Cl-RFW1	10	562.700	562.700	1073.846	2026.960	2577.430	3707.760	3707.760
Cl-RFW3	10	915.824	915.824	1968.427	2112.281	2695.500	3461.600	3461.600
Cl-RFW4	11	284.779	284.779	608.318	1811.600	2450.848	4282.100	4282.100
Cl-RFW5	8	1039.978	1039.978	6311.215	8513.296	16119.465	26101.100	26101.100
Cl-RFT1	8	2214.900	2214.900	2219.000	2278.894	2453.263	2797.322	2797.322
Cl-GFW1	9	10376.000	10376.000	13002.934	19800.600	25702.165	29867.200	29867.200
Cl-GFW2	9	11697.693	11697.693	28617.000	42684.300	107796.145	196624.320	196624.320
Cl-GFW3	9	24099.191	24099.191	38913.833	48590.600	87959.517	115120.087	187086.392
Cl-TCW1	6	68907.082	68907.082	98260.008	111853.609	185122.594	195494.760	195494.760
Cl-TCW2	6	99904.000	99904.000	111114.408	118870.118	148432.171	167237.810	167237.810
Cl-HFS1	7	980.419	980.419	1081.576	1241.046	1260.935	1508.623	1508.623
Cl-RFS2	10	162.200	162.200	367.400	893.513	1070.556	1189.451	3899.097
Cl-TCS1	6	8613.736	8613.736	10131.893	11468.048	15157.838	18246.072	18246.072

PARAM-SITE	N	LOOUFEN	LOINFEN	LO4TH	MEDIAN	UP4TH	UPINFEN	UPOUFEN
Cl-WS1	6	9553.005	9553.005	10515.648	11862.282	16079.733	20994.585	20994.585
Cl-HFFB	1	1052.340	1052.340	1052.340	1052.340	1052.340	1052.340	1052.340
Cl-RFFB	9	360.479	360.479	466.568	540.917	692.900	750.800	750.800
Cl-GFFB	4	525.500	525.500	587.700	697.850	749.750	753.700	753.700
Cl-WFB	5	499.192	499.192	575.594	747.210	759.032	759.032	1190.928
Cl-ILBF	10	474.099	474.099	519.400	619.745	778.672	794.795	1196.000
Cl-ILBU	6	461.224	461.224	473.500	545.147	780.771	1195.000	1195.000
SO4-SRS1	2	3495.300	3495.300	3495.300	3798.339	4101.379	4101.379	4101.379
SO4-RFS1	12	3819.500	3819.500	5127.430	5974.694	6705.944	6989.400	41556.309
SO4-SRS2	2	5045.400	5045.400	5045.400	5095.004	5144.608	5144.608	5144.608
SO4-HFS2	7	6844.901	6844.901	7167.579	7291.953	7639.974	7875.947	8406.702
SO4-RFW2	9	8316.400	8316.400	8488.860	8869.112	9763.200	10722.035	12108.823
SO4-WW1	6	15434.290	15434.290	18809.984	21894.309	24365.431	28094.793	28094.793
SO4-WW2	6	10917.754	19493.585	19493.585	21959.475	23580.670	29150.561	29150.561
SO4-HFW1	7	7404.687	7404.687	7832.864	8151.744	8251.868	8292.786	9210.000
SO4-HFW2	7	8918.622	10456.597	10480.275	10610.662	11037.116	11243.471	11243.471
SO4-RFW1	10	2423.000	2423.000	5760.728	8459.679	11148.272	11397.300	70641.806
SO4-RFW3	9	11807.638	11807.638	12575.486	13294.800	13989.270	14776.706	68646.813
SO4-RFW4	11	3459.104	3459.104	7296.850	23559.697	34374.289	37141.978	102805.006
SO4-RFW5	8	9409.236	9409.236	12506.434	16604.808	48394.065	95681.957	95681.957
SO4-RFT1	8	5970.773	5970.773	7156.851	7941.150	8348.300	8371.900	11974.214
SO4-GFW1	9	17579.100	17579.100	18311.712	20494.600	23019.000	27174.000	27174.000
SO4-GFW2	9	9656.705	9656.705	12071.000	13539.818	16690.500	17978.482	17978.482
SO4-GFW3	9	11616.039	11616.039	14745.244	15454.429	17937.900	22167.965	22167.965
SO4-TCW1	6	9626.347	9626.347	10172.010	12643.969	13881.951	14212.475	14212.475
SO4-TCW2	6	11837.139	11837.139	12748.995	13767.060	17917.000	17917.000	129822.851
SO4-HFS1	7	5380.629	5380.629	5971.735	6206.510	6544.609	6992.060	6992.060
SO4-RFS2	10	2059.800	4116.700	5332.826	6526.157	7224.934	7657.404	25975.261
SO4-TCS1	6	6480.543	6480.543	6530.000	7331.068	7591.896	7722.963	7722.963
SO4-WS1	6	6574.685	6574.685	6601.175	7730.918	8169.564	8201.679	8201.679
SO4-HFFB	1	136.894	136.894	136.894	136.894	136.894	136.894	136.894
SO4-RFFB	9	6.809	6.809	81.848	216.300	307.800	404.700	404.700
SO4-GFFB	4	193.500	193.500	194.600	215.500	292.400	349.500	349.500
SO4-WFB	5	4.566	4.566	10.460	19.233	73.400	77.980	77.980
SO4-ILBF	10	6.541	6.541	38.000	109.329	223.700	390.100	390.100
SO4-ILBU	6	9.918	9.918	17.000	36.121	83.500	83.500	234.630