Mid-Atlantic Coastal Streams Study: Statistical Design For Regional Assessment and Landscape Model Development

EMAP Symposium 2002
Wednesday, May 8
Kansas City, MO

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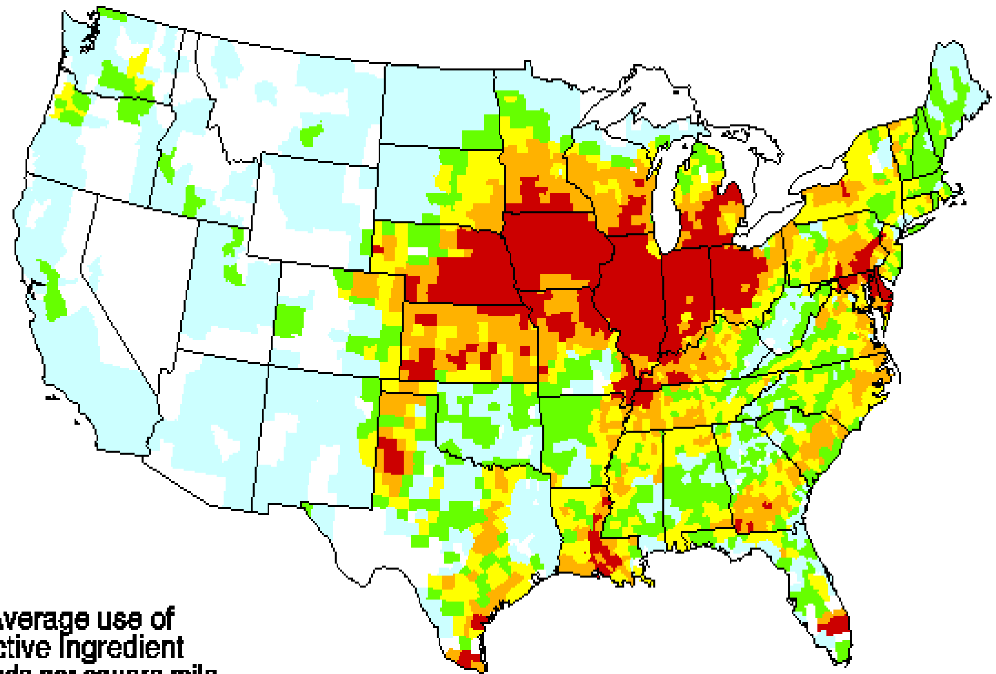
ATRAZINE

ESTIMATED ANNUAL AGRICULTURAL USE



Average use of Active Ingredient Pounds per square mile of county per year

- No Estimated Use
- < 1.080
- 1.080 – 5.587
- 5.588 – 21.211
- 21.212 – 66.515
- >= 66.516

Crops	Total Pounds Applied	Percent National Use
corn	53, 796, 206	84. 13
sorghum	7, 339, 963	11. 48
sugar cane: sugar & seed	1, 711, 322	2. 68
pasture	518, 074	0. 81
sweet corn	444, 523	0. 70
sod	119, 182	0. 19
prosomillet	11, 937	0. 02
field and grass seed	6, 305	0. 01

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LIPS Research Objectives

- Develop landscape indicator statistical models for pesticides, nutrients, sediments, and toxic chemicals, nationwide.
- Apply these models to perform area-wide assessments, prioritize stream conditions, and evaluate land use "what if" scenarios in conjunction with Region/State stakeholders.
- Provide these models to the software"tool kit" in preparation.

LIPS-MACS Objectives

- Characterize for small streams in the Mid-Atlantic Coastal Plain
  - water and sediment chemistry
  - benthic communities
  - physical habitat
- Identify landscape and geochemical factors that affect stream ecology and the quality of shallow ground water and small streams in the Mid-Atlantic Coastal Plain

LIPS-MACS Objectives continued

- Develop landscape indicator statistical models, based on landscape “metrics” (i.e., measures of land use, soils, geology)
- Use these models to assess current conditions for, and predict of the occurrence and distribution of
  - pesticides and nutrients in streams,
  - pesticides and toxic substances in bed sediment, and
  - benthic communities

Unique Features of Study

- Choosing first order streams and watersheds
- Incorporating hydrogeologic framework into the sampling design
- Combining a gradient study sampling design with a probability sampling design to address multiple objectives
- Incorporating soils, geologic, and hydrologic data into the landscape indicator model development process
- Developing landscape indicator models for pesticides and toxic substances
- Characterizing pesticide metabolite concentrations for the freshwater streams of the Mid-Atlantic Coastal Plain

Design

- Combination of two competing approaches:
  - Random, probability-based design
  - Targeted sampling
- Selected 175 sites for a base network using a stratified variable-probability approach to ensure desired land-use distribution.
  - Stratified on the basis of hydrogeology
  - Adjusted site-selection probabilities on the basis of land use
- Sampling of additional hand-picked reference sites, and nested sites located in watersheds with temporal sampling.

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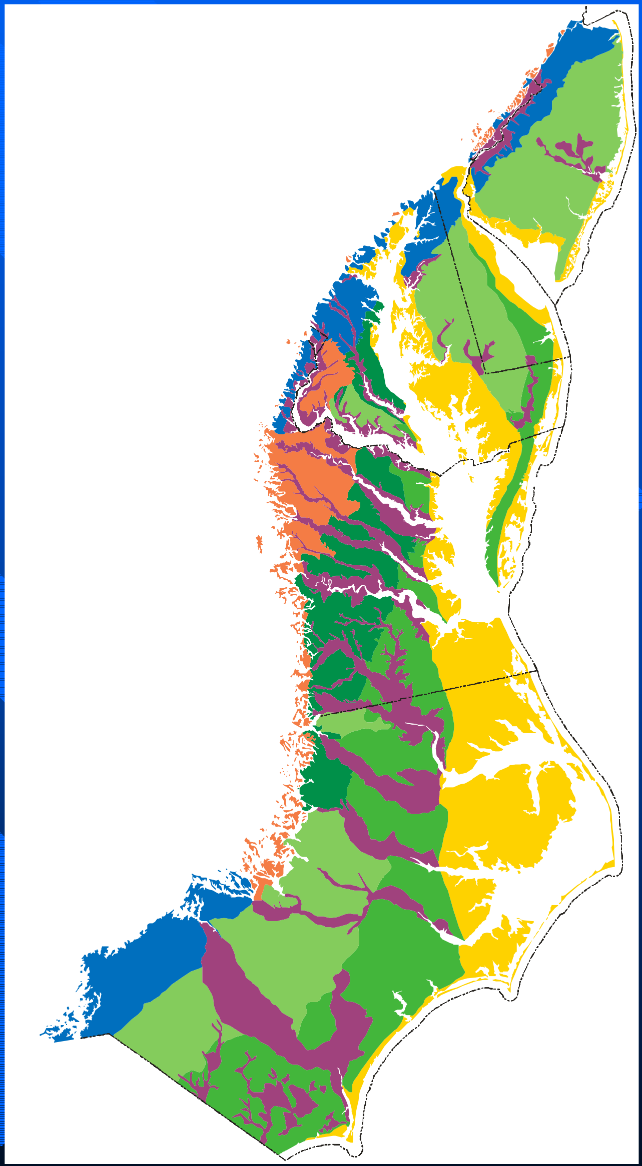
Strata - Hydrogeologic Framework

- **FW1**: Coastal Lowlands
- **FW2**: Middle Coastal Plain, Mixed sediment texture
- **FW3**: Middle Coastal Plain, Fine sediments
- **FW4**: Middle Coastal Plain, Sands with overlying gravels
- **FW5**: Inner Coastal Plain, Upland Sands and Gravels
- **FW6**: Inner Coastal Plain, Dissected Outcrop Belt
- **FW7**: Alluvial and Estuarine Valleys



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Hydrogeologic Framework

FW1 – Coastal Lowlands

- very flat and low lying, poorly drained, primarily fine estuarine and near-shore marine sediments; abundant organic matter
- ammonia and organic N dominate, nitrate concentrations are low; little pesticides transported through soil to ground water, except in rare sandy areas

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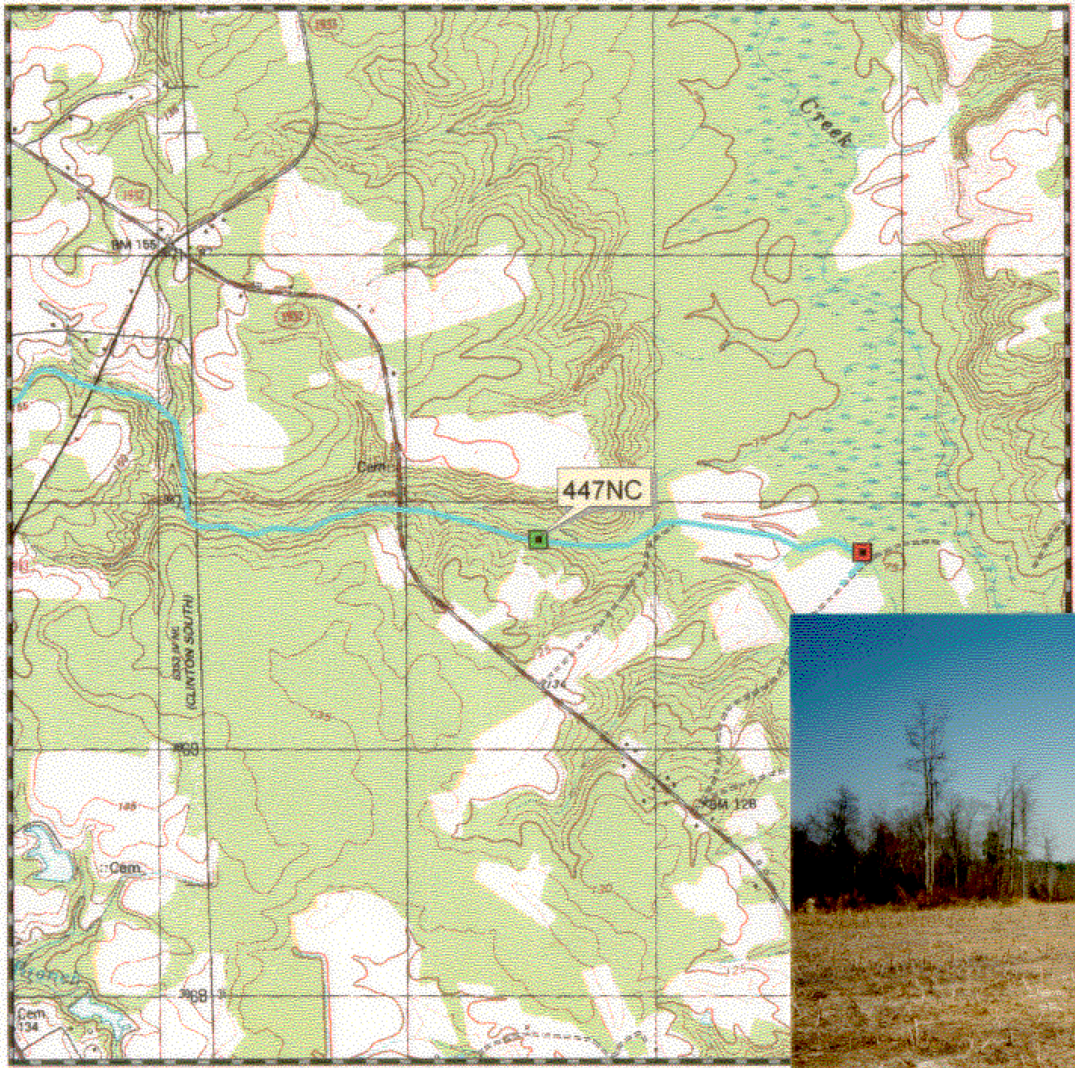
Hydrogeologic Framework

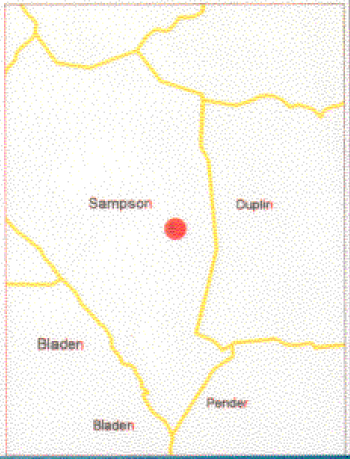
FW4 - Middle Coastal Plain, Sands with Overlying Gravels

- moderately dissected marine inner-shelf sands overlain by fluvial sands and gravels in New Jersey and Delmarva Peninsula
- nitrate dominates nitrogen speciation; high potential for nitrate and pesticide transport through sandy soils to ground water

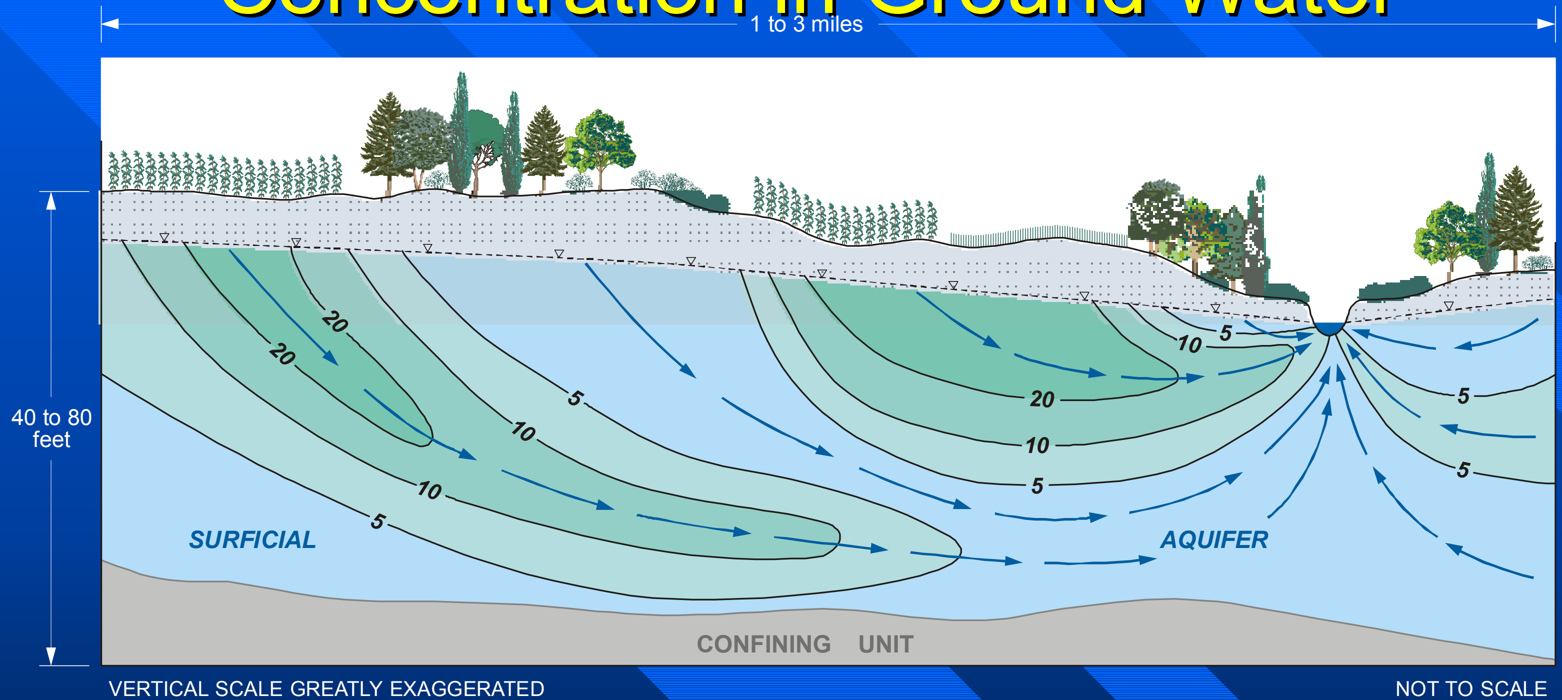
Site 447NC DRG



Location Map



Relation Between Land Use and Nitrate Concentration in Ground Water



EXPLANATION

UNSATURATED ZONE

SURFICIAL AQUIFER

CONFINING UNIT

10 — CONTOUR OF NITRATE CONCENTRATION IN GROUND WATER, IN MILLIGRAMS PER LITER AS NITROGEN

GENERALIZED DIRECTION OF GROUND-WATER FLOW

WATER TABLE

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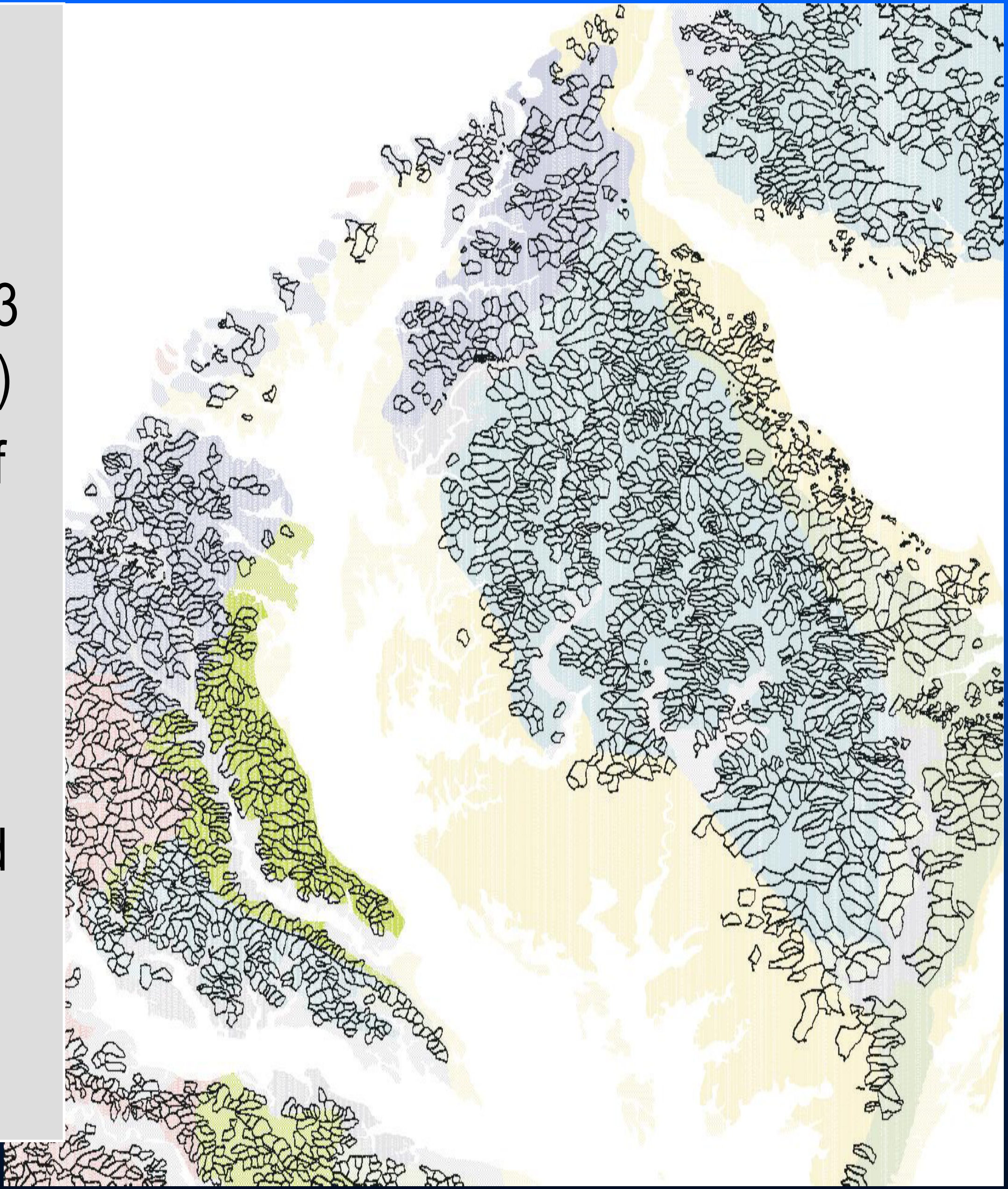
Base Network Design

- Target population: fresh, non-tidal, first-order streams in the Mid-Atlantic Coastal Plain (to be sampled once during late winter, early spring baseflow)
- Random selection of 25 sites within each of seven hydrogeologic subregions (total=175)
- Selection probabilities were adjusted to ensure approximately even distribution of sites along a land-use gradient within each subregion

Base Network Design

- Started with population of RF3 “Start” reaches (1:100K scale)
- Masked out estimated area of tidal effects
- Estimated watersheds by Euclidean method
- Determined land-use distribution in each watershed
- Selected sites along land-use gradient within each hydrogeologic subregion



Base Network Design
Unequal Probability Sampling

- In Simple Random Selection, each site in the target population has an equal probability of being selected, and the distribution of selected sites will (on average) match the distribution of the target population.

- For Unequal Probability Sampling, selection probabilities can be adjusted to fit a desired distribution. Data are then weighted at the analysis stage with the inverse of the selection probability (to make probabilistic assessments).

Base Network Design
Unequal Probability Sampling

- In each hydrogeologic subregion, sites were selected along a gradient of land use (defined by percent developed).

Subregion	Percent Developed	Population Sites N_T	Expected Sites n_E	Inclusion Probability $p = n_E/N_T$	Initial Weight $W_I = 1/p$
5	0 to 19	277	5	0.018	55.4
	20 to 39	253	5	0.020	50.6
	40 to 59	147	5	0.034	29.4
	60 to 79	64	5	0.078	12.8
	80 to 100	9	5	0.556	1.8

- Initial weights are applicable for assessments based on all sampled sites and can be adjusted if sites are rejected and replaced.

Base Network Design

Distribution of Selected Primary and Alternate Sites

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Base Network Alternate Sites

- To preserve design, had to be included in groups of 5
- The alternate data set was grouped randomly without consideration of geographic location or land use.
- Goals: 23-27 sites in each hydrogeologic subregion (strata) and maintenance of the land-use gradient
- When the total sites available to sample in a subregion went below 23, a group of alternates was included.
- Added other alternates to maintain land-use gradients

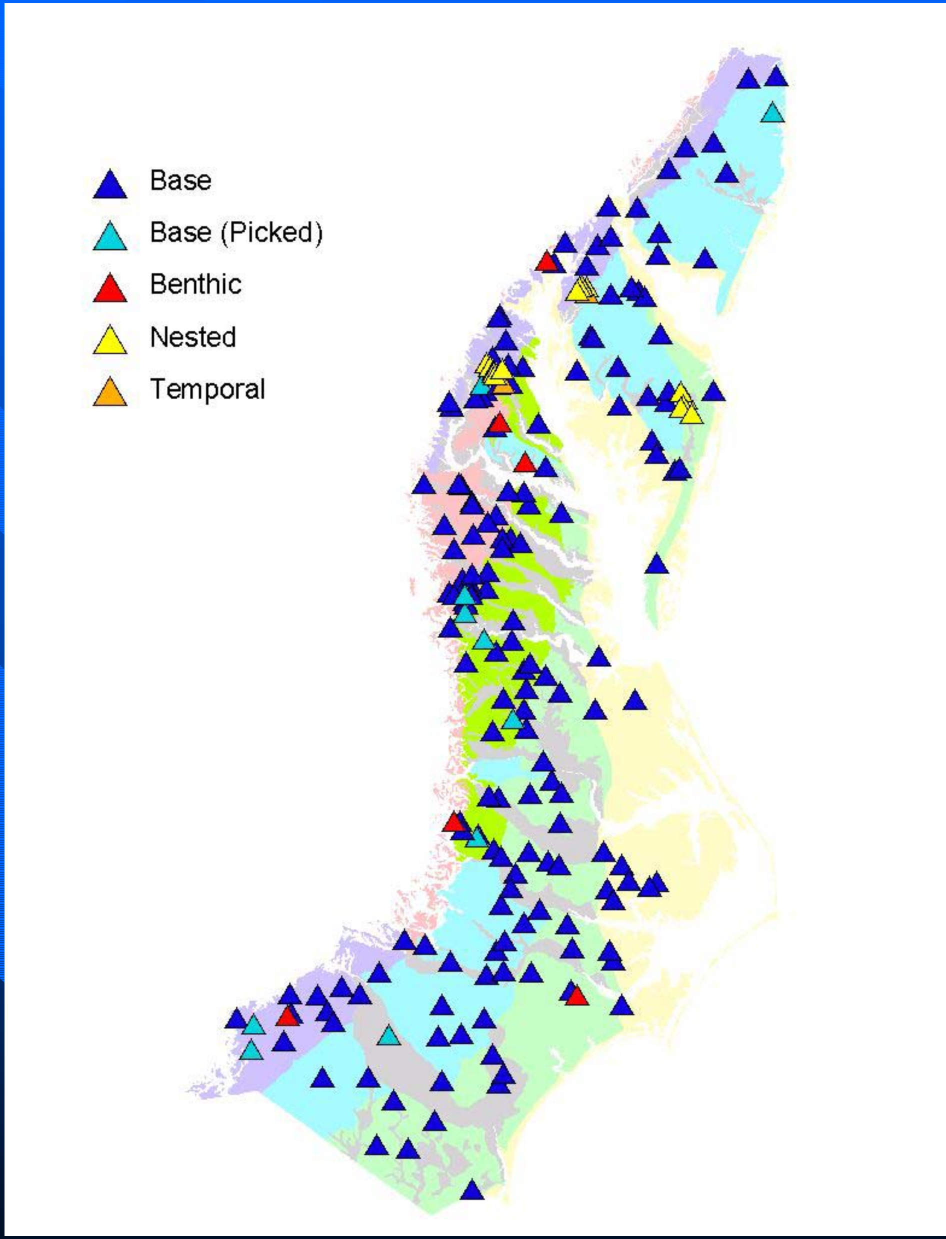
Reconnaissance - Results

Status	FW 1	FW 2	FW 3	FW 4	FW 5	FW 6	FW 7	Other
Sampled	24	23	24	23	23	23	24	34
Rejected	6	12	15	12	2	12	11	6

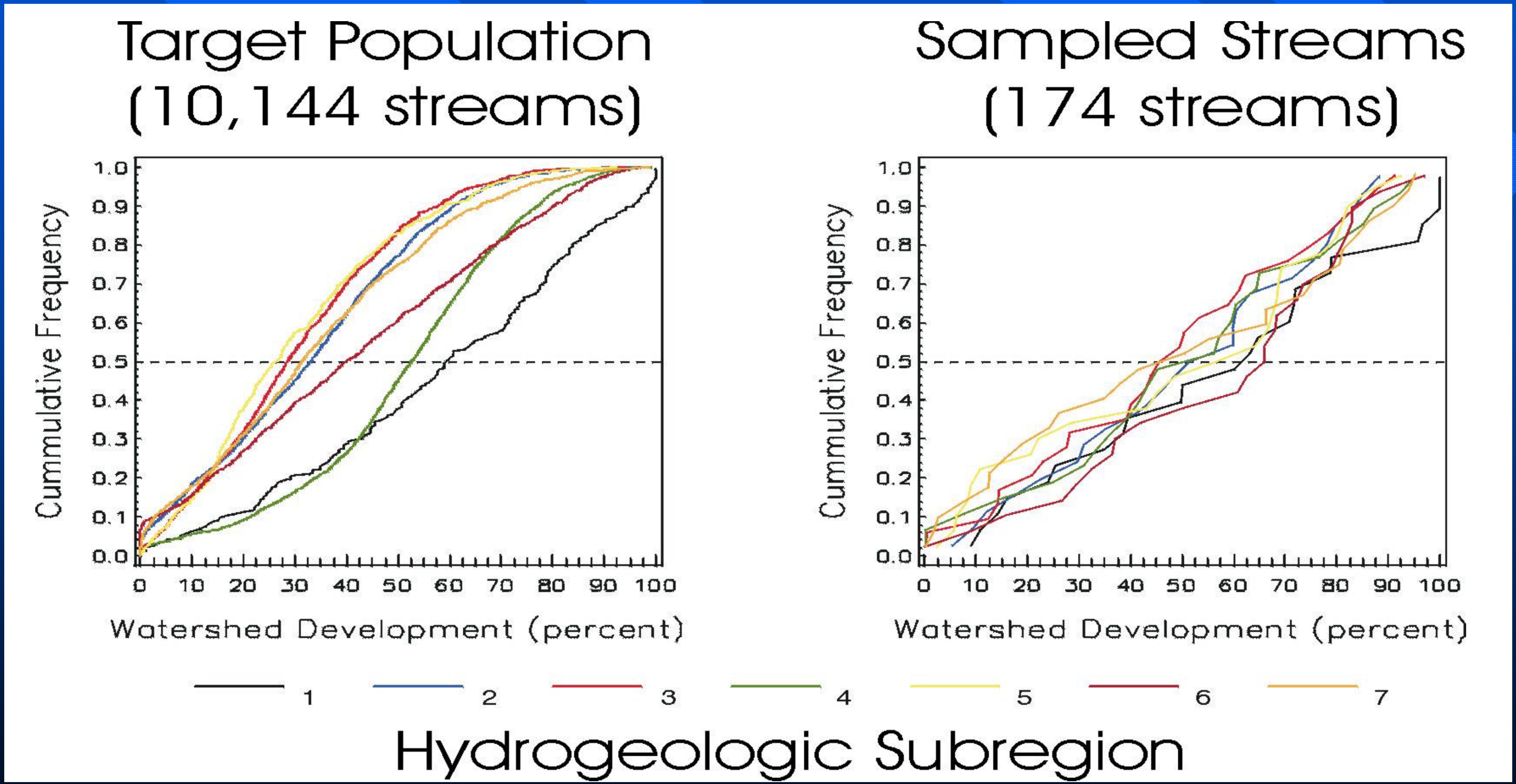
- 44 sites were inaccessible (mostly due to owner refusal, some for safety reasons)
- 32 sites were dropped because of site conditions (ie. tidal influence, too swampy, dry)

Final Sampling Network

198 Sites



Effects of random selection with adjusted probabilities on the design of the base network



Initial Results: Pesticides in MACS

Compound	Sample Detection Frequency (%)	Estimated Percent of Pop. gt 0.05 ug/L	Estimated Pop. Median (ug/L)
Total Pesticides	88	70	0.38
Metolachlor	72	10	0.007
Atrazine	62	5	<0.015
Metolachlor ESA	62	66	0.27
Desethylatrazine	50	8	<0.005
Prometon	43	1	<0.0018
Alachlor ESA	41	37	<0.05
Simazine	34	4	<0.01
Metolachlor OA	40	35	<0.05
Alachlor OA	23	19	<0.05
Alachlor	16	3	<0.013
Diazinon	12	2	<0.009
Tebuthiuron	13	4	<0.01
Carbaryl	11	-	-

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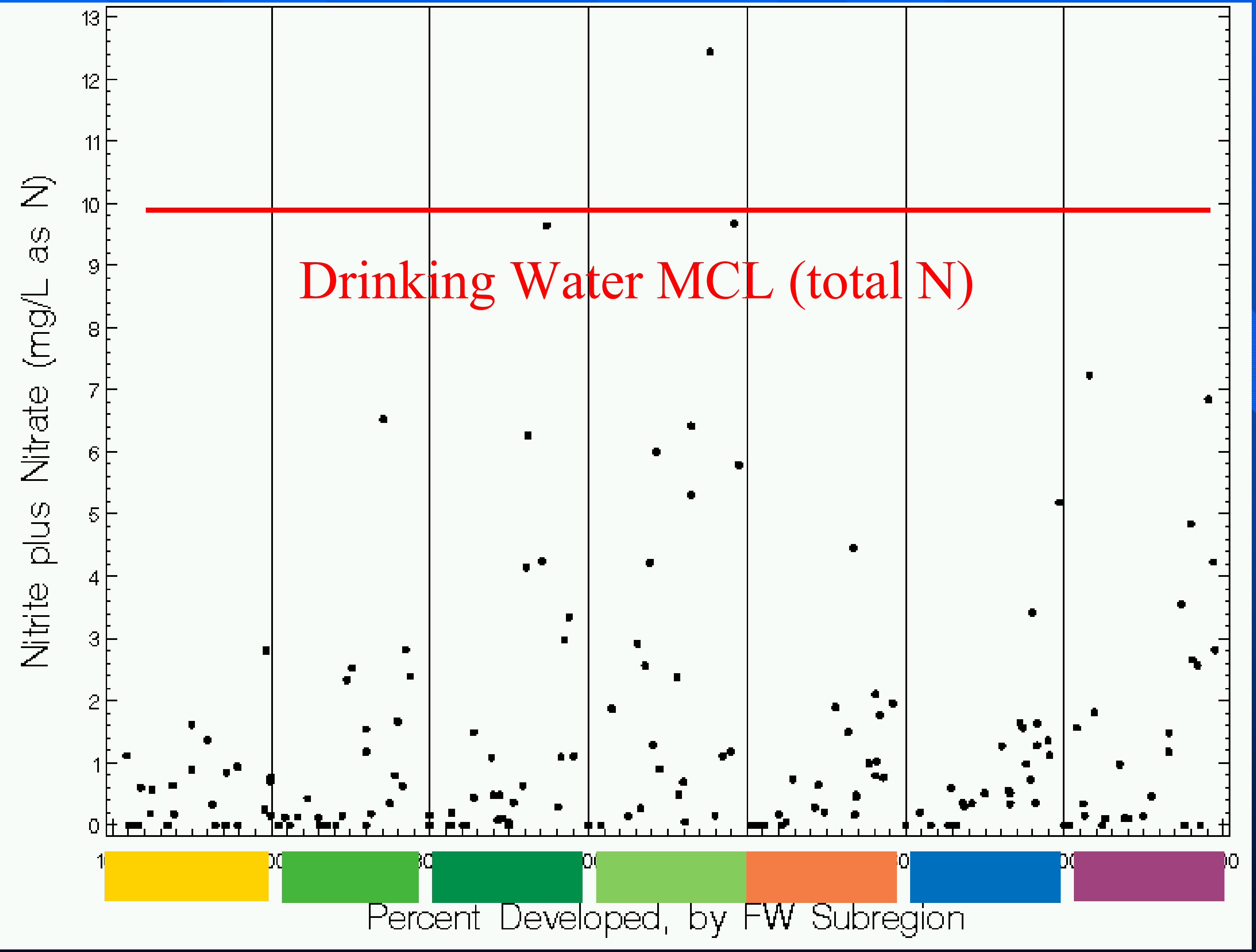
Initial Results: Nutrients



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Regression Modeling

- Dependent Variables
  - pH, DO, SC, alkalinity
  - pesticides and metabolites in water
  - major ion chemistry
  - nutrients in water
  - benthic communities
  - physical habitat
- Explanatory Variables
  - Percent and distribution of land cover types
  - Watershed slope
  - Stream density
  - Chemical applications
  - Road density
  - Precipitation
  - Soil parameters

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Landscape Indicator Statistical Models for Nitrogen
(dissolved nitrate+nitrite+ammonia+organic nitrogen)

Subregion	*Equation*	*Var. Explained*
1 Coastal Lowlands	Log (N + 0.01) = -0.0566 + 0.3839 Land10 + 0.1761 Soil4	0.63
2 Middle-Mixed	Log (N + 0.01) = 0.0891 + 0.2489 Land6 + 0.1528 Soil1	0.56
3 Middle-Fine	Log (N + 0.01) = 0.0899 + 0.2525 Land1	0.36
4 Middle-Sand-Gravel	Log (N + 0.01) = 0.2558 + 0.3230 Land1 - 0.2837 Land9 - 0.2869 Land12 + 0.1865 Soil5	0.76

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Landscape Indicator Statistical Models for Nitrogen
(dissolved nitrate+nitrite+ammonia+organic nitrogen)

Subregion	*Equation*	*Var. Explained*
5 Dissected-Sand-Gravel	Log (N + 0.01) = 0.0901 + 0.4148 Land1	0.70
6 Inner	Log (N + 0.01) = 0.0022 + 0.3572 Land1	0.80
7 Alluvium-Estuarine	Log (N + 0.01) = 0.1047 + 0.1860 Land1 + 0.2459 Soil5	0.49

Metrics in Principal Components

Land 1 = + % agriculture, % urban, U-Index, human use in riparian zone, agricultural use in riparian zone; - % forest, % wetland, forest riparian zone, pff9, forest edge 9, forest interior

Land 6 = + interior forest, interior patch size, core forest, perforated Ag; - forest edge, perforated forest, ag patch size (9)

Land 9 = + mean slope, wetland in riparian zone, elevation SD; - golf courses

Land 12 = + # forest patches, % barren; - golf courses, riparian barren, forest edge, agriculture on steep slopes

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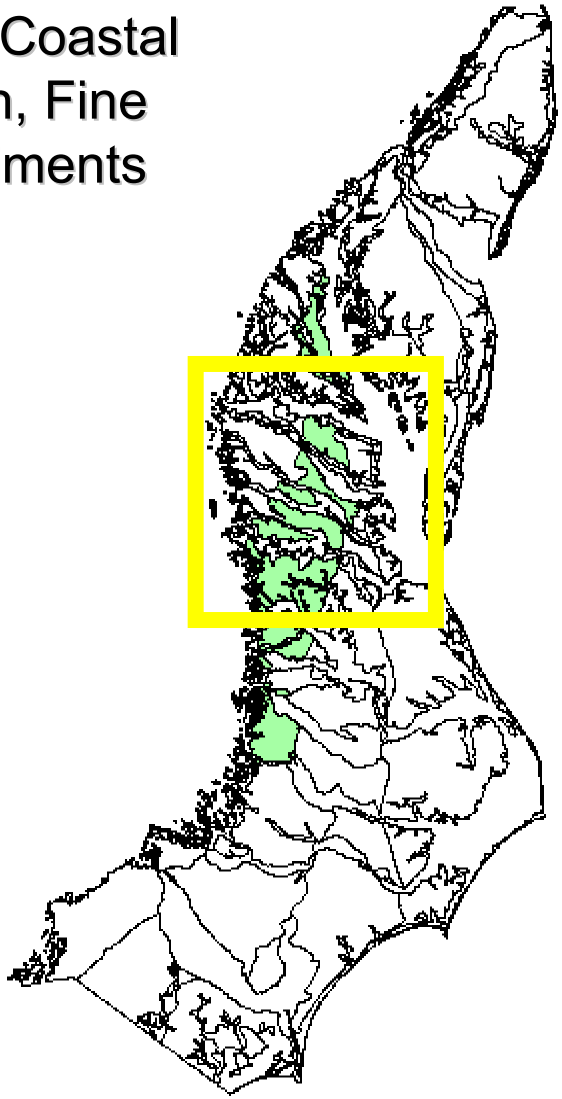
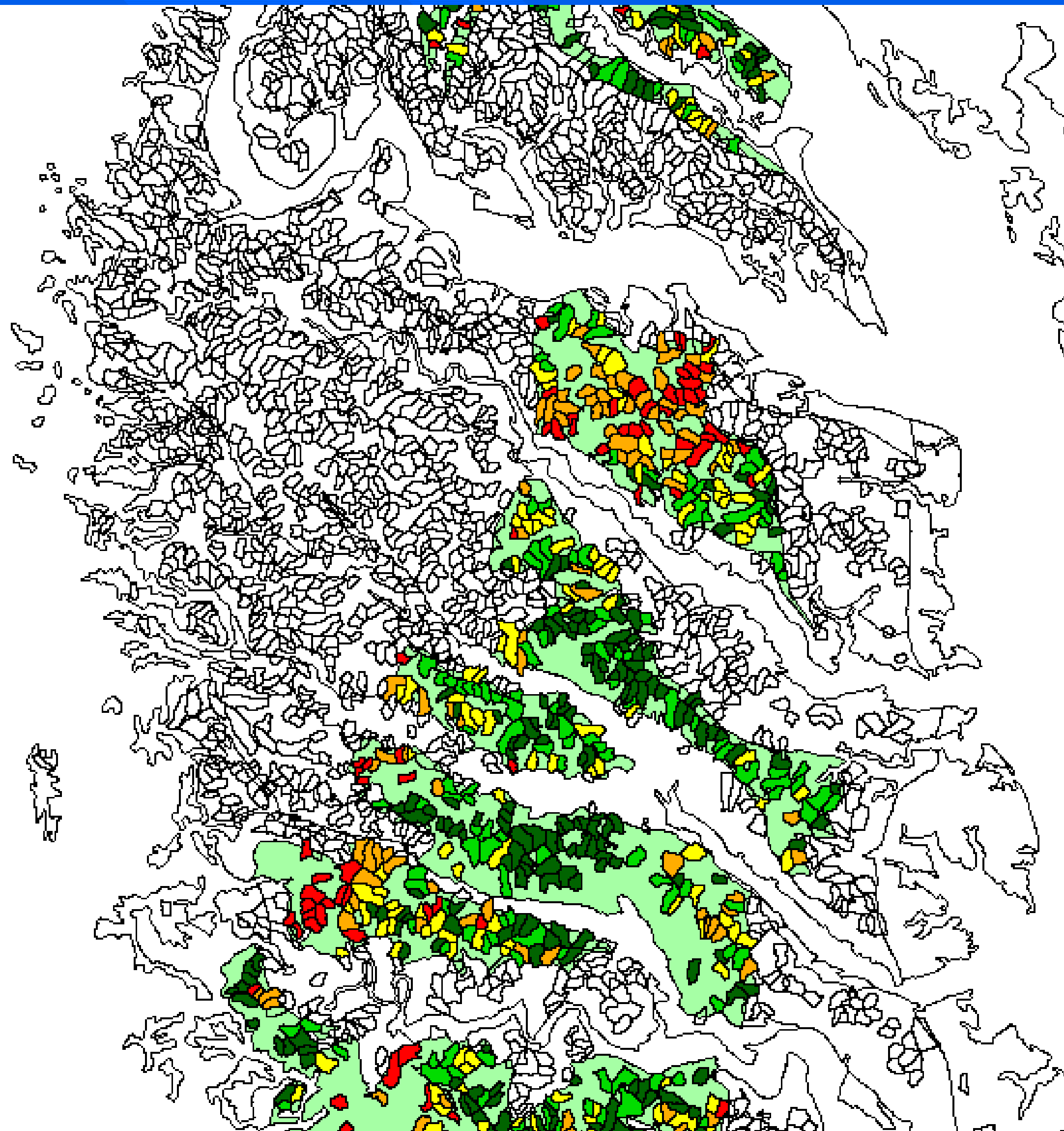
Estimated Total Nitrogen, South of
ac R.

SUBREGION 3

Mid-Coastal Plain, Fine Sediments





Quintile Plot

Initial Findings

- Low concentrations of pesticides were present in over 75% of the first-order streams.
- Ecoregional nutrient criteria were exceeded at 40 percent of sites (Total N) and 68 percent (Total P).
- Chemical conditions in streams vary with land use
- The response of streams to land development varies across hydrogeologic settings

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Implications

- The presence of nutrients and pesticides in streams during baseflow conditions indicates these chemicals are widespread in shallow ground water of the Coastal Plain used for drinking water.
- Different mitigation strategies may be needed for different areas to achieve the same degree of protection of water quality.

Next Steps: LIPS-MACS

- Continue statistical modeling (stepwise regression, ANCOVA, CART)
- Calculate pesticide application quantities via crop proportion estimates, incorporate into models
- Analyze benthic macroinvertebrate data and sediment data sets , incorporate into models
- Apply statistical models to 10,000+ first order watersheds, identify watersheds at risk
- Work with stakeholders to customize results to local needs and issues
- Develop Atlas for Mid-Atlantic Coastal Streams

Next Steps:
If interested in the planning of Midwest Study, or study updates please contact us

- Sign-up sheet
- Email or call Ann Pitchford at:
  pitchford.ann@epa.gov
  (702) 798-2366

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Next Step: Planning the Midwest Study

- Develop Midwest plan in FY02
- Review existing data
- Interact with others working in area to see what leverage is possible (NAWQA, EMAP, Army Corps of Engineers, EPA Regions, States)
- Involve EPA Regions, States, OPPTS and OW staff (on general priorities, study design, chemicals of interest, types of statistical analyses)

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Initial Results: Nutrients

Compound	Sample Detection Frequency	Ecoregional Nutrient Criteria (Aggregate Ecoregion XIV)	Samples Exceeding Criteria (Percent)
Total Nitrogen	-	0.71 mg/L	-
Ammonia + Organic N tot	99	-	25
NO2 + NO3	77	-	40
Total P	97	0.03 mg/L	68
Dissolved P	99	-	-

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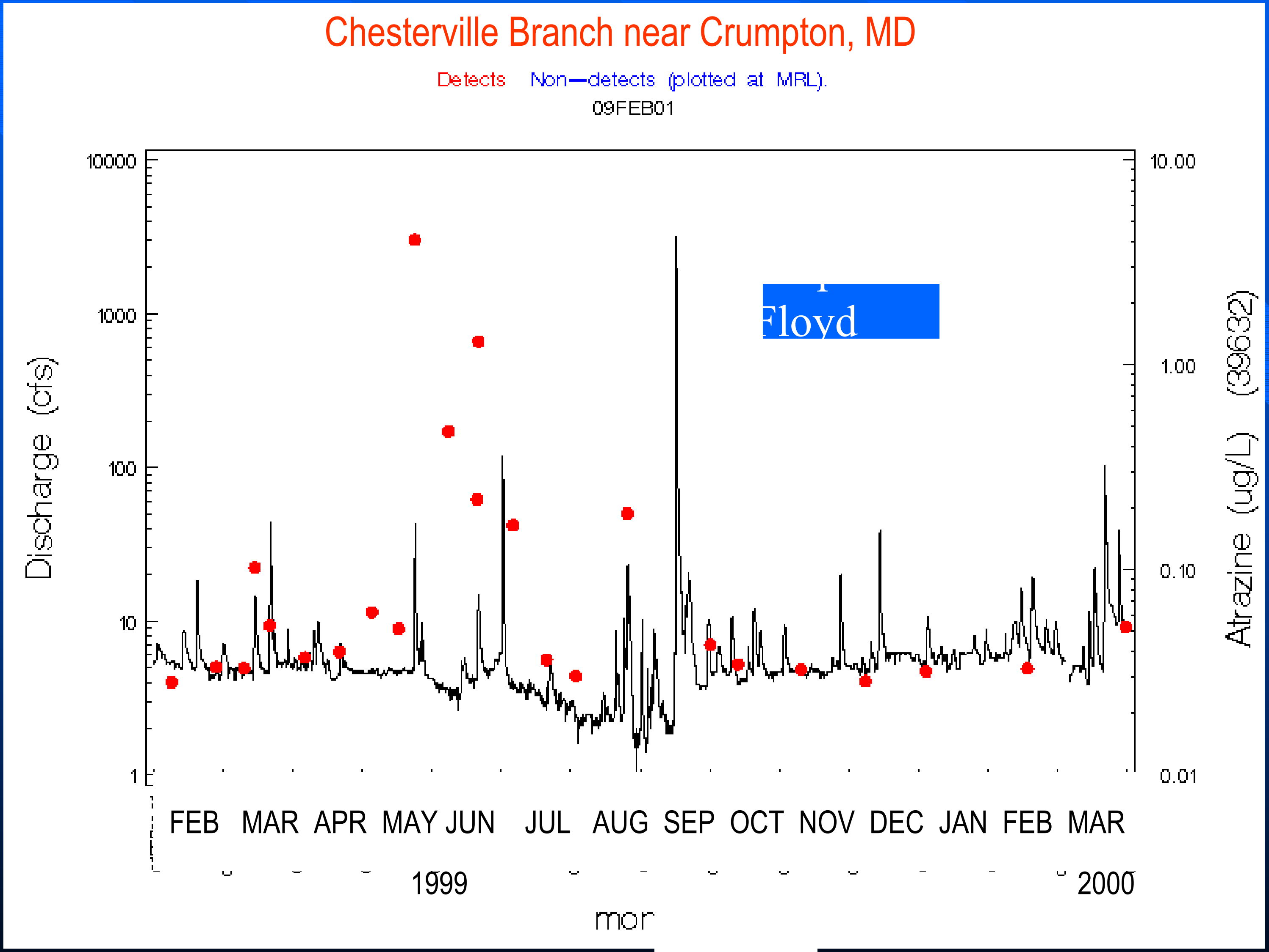
Initial Results: Atrazine



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