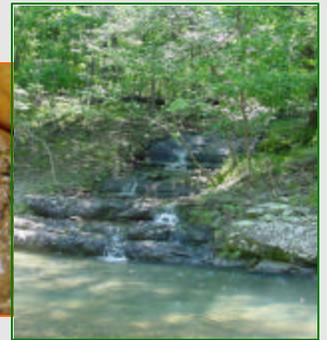


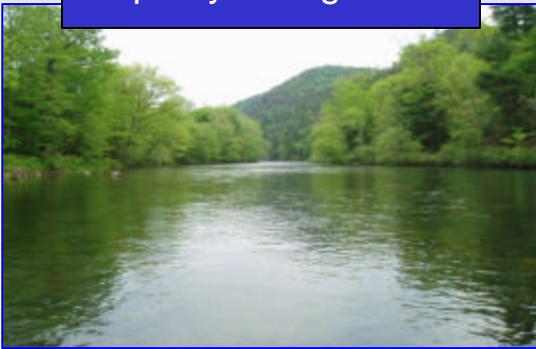
Virginia's Freshwater Probabilistic Monitoring Program

What is Probabilistic Monitoring?

Probabilistic monitoring (ProbMon) is the sampling of randomly selected stations. These monitoring stations are generated by a computer program that randomly chooses monitoring sites on rivers and streams throughout Virginia. Water quality monitoring stations in Virginia are typically located at bridges. These monitoring stations are known as targeted monitoring sites.



How good is the water quality in Virginia?



Targeted monitoring has utility for monitoring regulatory compliance of pollution sources, identifying impaired waters, and for tracking local pollution events. However, it is not appropriate to extrapolate results from targeted stations to unsampled watersheds over large geographic areas. Data to answer such questions are best obtained from sample locations chosen so that all streams have an equal chance of being sampled. Consequently, to answer the question "How good is the water quality in Virginia?", a new more comprehensive data set was needed.

In order to address statewide and regional questions about water quality, the Virginia Department of Environmental Quality (VDEQ) added probabilistic monitoring networks to its estuarine monitoring program in 2000 and its freshwater monitoring program in 2001. This document will focus on the freshwater program. The aim of ProbMon is to provide accurate statewide and regional assessments of the chemical, physical, and biological conditions of Virginia's freshwater resources.

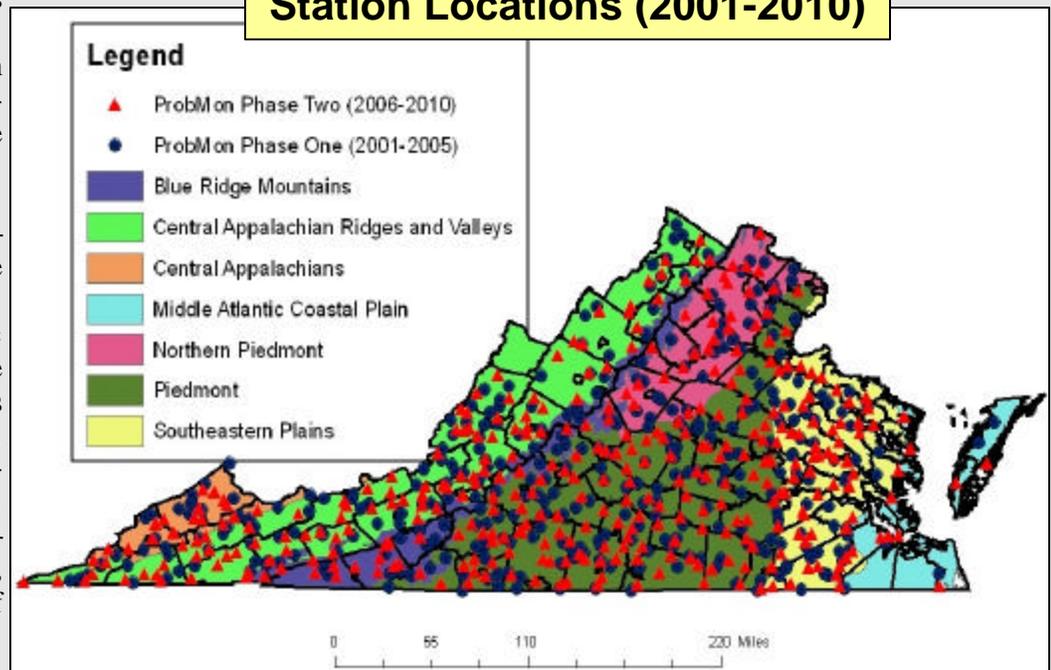
Station Locations

ProbMon sampling points were generated by the United States Environmental Protection Agency (USEPA) using a sampling design similar to USEPA's Environmental Mapping and Assessment Program (EMAP). ProbMon samples at 50 to 60 randomly selected stations per year throughout the Commonwealth for a variety of chemical, biological, and habitat parameters.

It is important to sample chemical (i.e. nutrients and metals), biological (i.e. algae and benthic macroinvertebrates), and habitat (i.e. total habitat surveys and relative bed stability) parameters in streams because overall stream health requires optimal habitat and water chemistry to support healthy biological communities.

ProbMon sites include streams and rivers of various sizes and different geographic regions. By 2010, VDEQ expects to have sampled nearly 600 stations.

Station Locations (2001-2010)



ProbMon Results

BIOLOGICAL MONITORING

Biological monitoring of streams and rivers is an integral component of Virginia's water quality monitoring program. Biological monitoring allows VDEQ to assess the ecological condition of streams and rivers. Biological surveys are used to answer the question of whether these waterbodies support survival and reproduction of a diverse group of aquatic organisms.

Using probabilistic data collected from 2001-2004, Virginia has validated the VSCI using a spatially diverse dataset. This probabilistic dataset has allowed VDEQ to narrow data gaps and test the proposed VSCI against many classification variables, which include season, stream size, ecoregion, bioregion, river basin, VDEQ region, and collection technique.

Biological Monitoring

- ✓ Utilizes macroinvertebrate communities
- ✓ Allows VDEQ to assess overall stream health
- ✓ Detects pollution that chemical sampling may miss



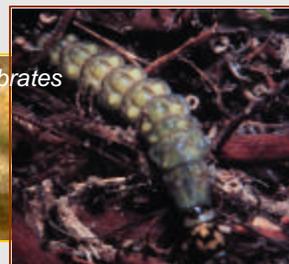
Validating the VSCI has allowed Virginia to improve biomonitoring assessments. Collecting the biological condition information in a probabilistic design allows VDEQ to estimate overall ecological integrity in the non-coastal areas of Virginia. Future biomonitoring using a probability design will allow VDEQ to determine if ecological integrity is improving or degrading in Virginia's streams and rivers.

In 2000, the USEPA contracted TetraTech, Inc. to develop a multimetric macroinvertebrate index in non-tidal streams for the Commonwealth of Virginia. This index contains eight core metrics, that when summed as one number is known as the Virginia Stream Condition Index (VSCI). TetraTech, Inc. developed the VSCI using Virginia's existing targeted biomonitoring database, which contained a limited number of reference sites in the central Appalachian ecoregion, both Piedmont ecoregions and in headwater streams.

Benthic Macroinvertebrates



Beetle Larvae

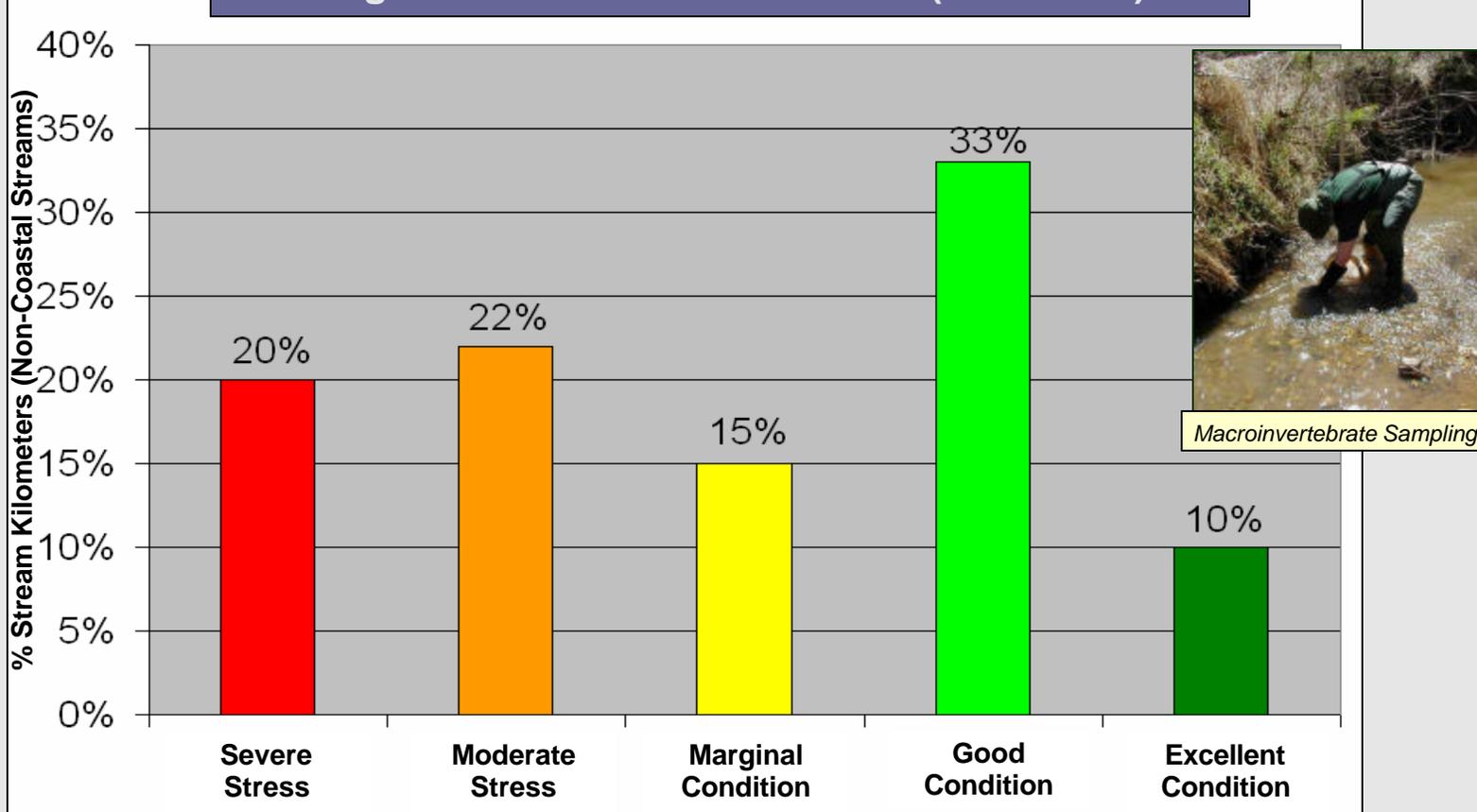


Caddisfly Larvae



Stonefly Larvae

Virginia Stream Condition Index (2001-2004)



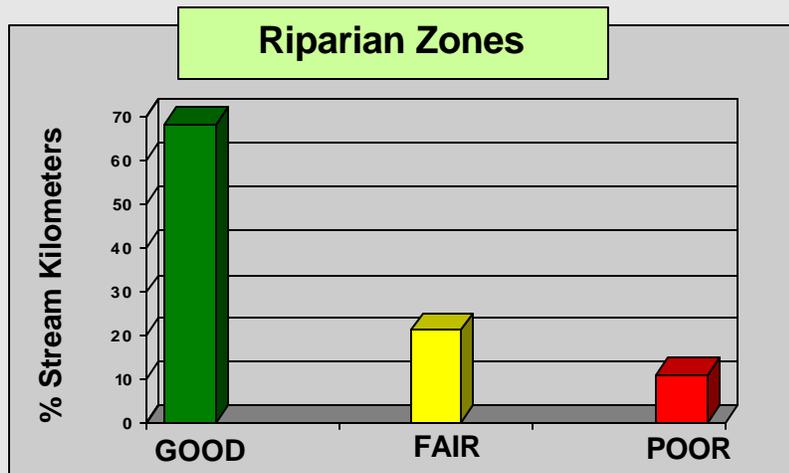
Macroinvertebrate Sampling

ProbMon Results

HABITAT CONDITION

Total Habitat scores can range from 0 to 200. An estimated 5% of stream kilometers was in *poor* condition (score <100). Statewide habitat scores showed that 52% was in *fair* condition and 43% was in *good* condition (score >150).

Riparian zones are the areas on the stream banks adjacent to the water. The scores for riparian buffer zones, or the stream banks, were good with nearly 70% of streams in Virginia receiving scores in the optimal range. Only 10% of Virginia streams received suboptimal riparian buffer scores.



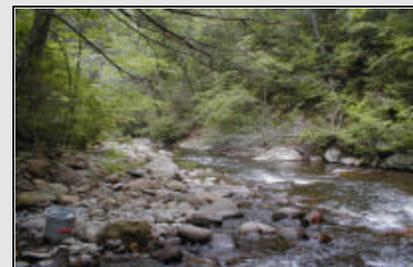
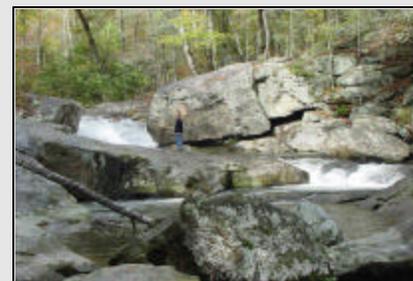
Relative Bed Stability

Sedimentation is one of the most prevalent impacts to benthic communities. Excess sediment fills interstitial spaces in the stream substrates used by aquatic organisms for habitat. Until recently, tools for rapidly quantifying sedimentation impacts in streams have been inadequate. Methods existed for describing dominant particle size, but it was difficult to differentiate between natural conditions and man-made problems. Virginia has a variety of stream types; many are naturally sand/silt bed streams, so simply measuring the size of the sediment particles cannot differentiate natural and human-influenced sediment load.

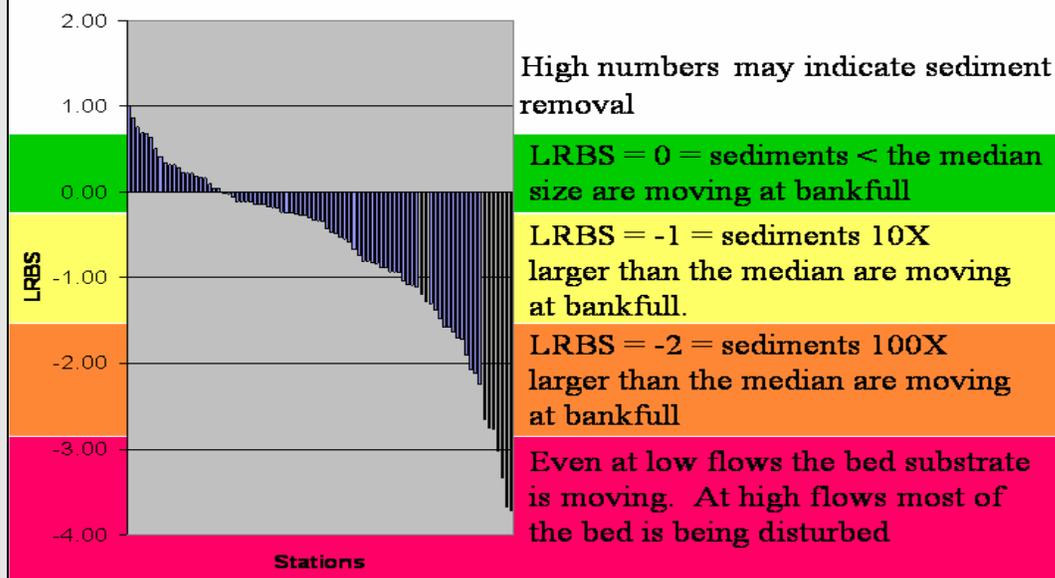
USEPA researchers have developed a tool for predicting the expected substrate size distribution for streams. This method incorporates stream channel shape, slope, flow and sediment supply. The method calculates a 'stream power' based on channel measurements to predict the expected sediment size distribution. The logarithm ratio of the observed sediment to the expected sediment is a measure of the relative bed stability (LRBS). An LRBS near zero indicates the stream is stable. However, increasingly negative numbers may indicate excess sediment.

VDEQ is collecting Relative Bed Stability data at ProbMon stations to determine its utility in separating human-influenced sediment problems from natural conditions. Efforts are focused on obtaining baseline data for different types of streams and no conclusions on stream health are being extracted from the data at this point.

Virginia Stream Diversity



Relative Bed Stability Frequency Distribution



ProbMon Results

NUTRIENTS

Nutrient enrichment has been identified as the cause of approximately half of the reported stream impairments nationwide. Characteristics of nutrient enriched streams can include low dissolved oxygen, fish kills, shifts in flora and fauna, and blooms of nuisance algae. Excess nutrients in streams may even cause human health problems. Nutrient enrichment can be a result of fertilizer runoff from non-point sources such as farms and lawns as well as from municipal and industrial point sources.



Algae covered rocks from a nutrient enriched stream (left) compared to rocks from a stream with a "normal" nutrient load (right).

Algae Study

Streams with excessive nutrients and adequate sunlight will have higher than normal algal growth. If algal growth is excessive, dissolved oxygen can be depleted during the night. Oxygen may also be scarce when plants decompose, resulting in impacts to fish and benthic macroinvertebrates.

Measures of water chemistry may underestimate the degradation of living systems from excess nutrients. Information from algae collection and identification provide a more accurate measurement of the effects of nutrients.

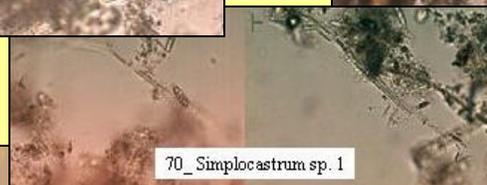
Recently there has been considerable research across the nation to develop biological indices that utilize algae communities. Algae communities, especially a subset of algae known as diatoms, are excellent ecological indicators of water quality. In 2004, VDEQ was able to contract the Patrick Center for Environmental Research to conduct a pilot project to develop algae-based indices for Virginia. VDEQ staff collected algae samples by scraping the algae from a representative amount of rocks at ProbMon stations. The pilot study showed promising results in explaining how nutrients such as Total Phosphorus and Nitrogen impact algae communities.

Photosynthesis



Through **photosynthesis** plants and algae utilize carbon dioxide and water to form plant tissue. Oxygen is released as a byproduct.

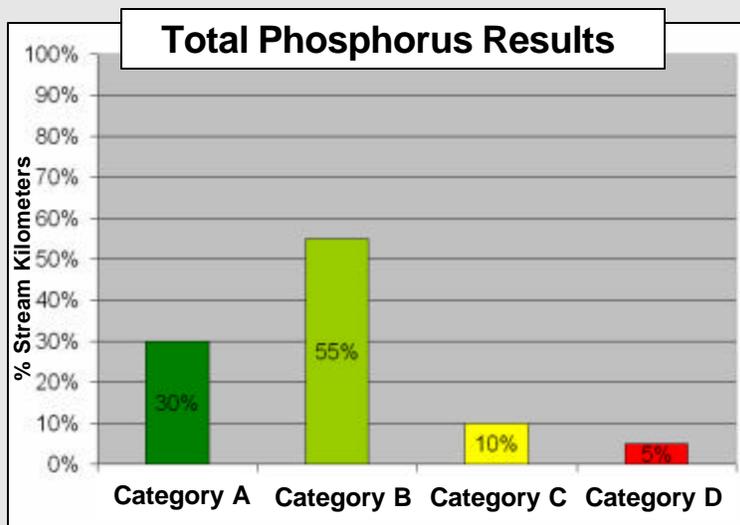
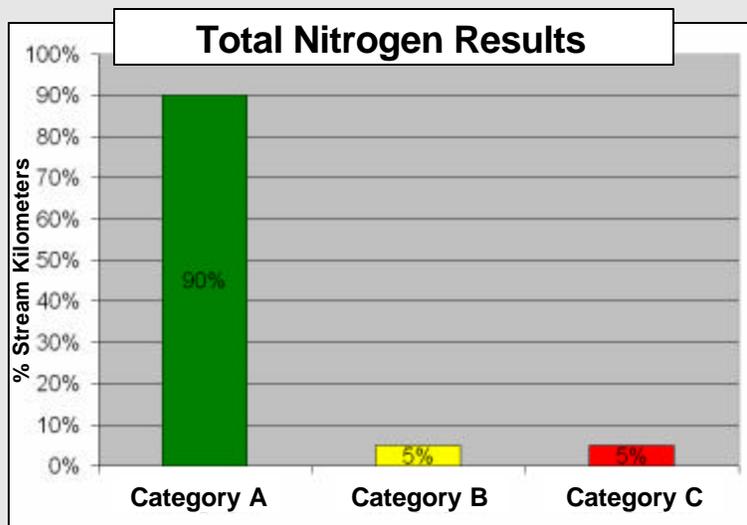
Plants and algae also respire whereby the photosynthesis equation reverses. **Respiration** utilizes plant biomass and oxygen and produces carbon dioxide and water as byproducts. **Decomposition** of dead plant material also reverses the equation and depletes oxygen.



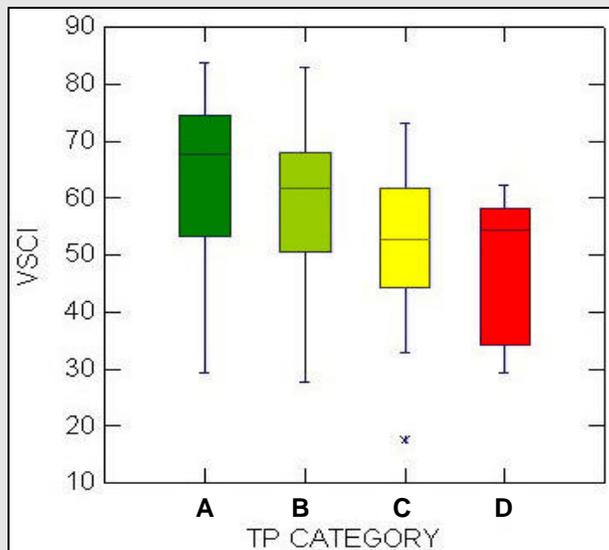
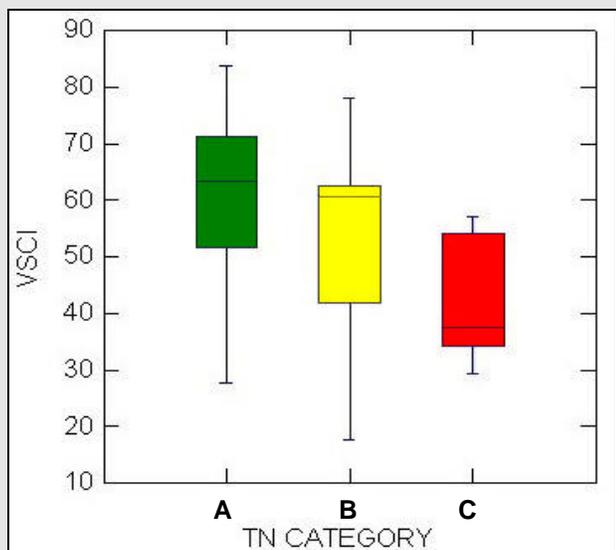
Examples of Virginia Algae Species

Photos courtesy of the Patrick Center

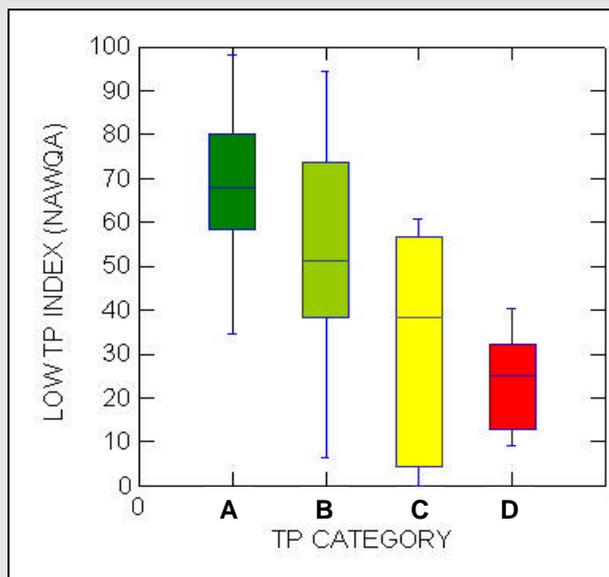
ProbMon Results



Total Nitrogen (TN) categories in the figures are: A) <1, B) 1-2, C) >2 mg/L and total phosphorus (TP) categories in the figures are: A) <0.01, B) 0.01-0.05, C) 0.05-0.1, D) >0.1 mg/L. In all of the graphs, nutrient concentrations increase from left to right. The bar graphs above show the statewide distribution of TN and TP in the water column. An estimated 10% of Virginia streams have a total nitrogen value above 1 mg/L and 5% of Virginia streams have total phosphorus level above 0.1 mg/L. The box plots below show algal and benthic (VSCI) indices versus total phosphorus and nitrogen. The Low TP index was developed by studying diatom species distributions along TP gradients. VSCI median values decrease as nutrient level category increases.



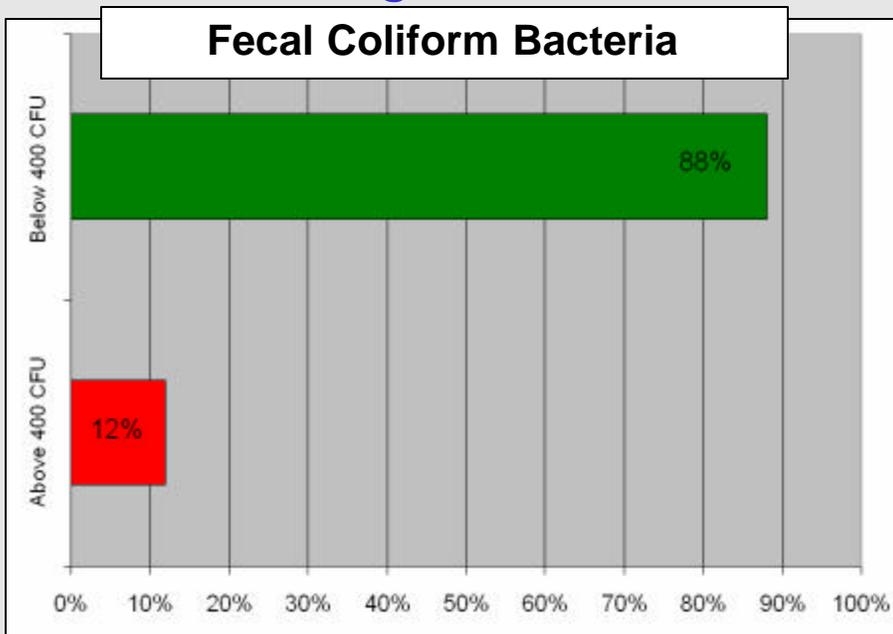
VDEQ staff process algae samples.



ProbMon Applicability to other VDEQ Programs

TOTAL MAXIMUM DAILY LOADS

Bacteria are found in the fecal matter of warm-blooded animals. High counts of bacteria in a stream indicate that there is an increased risk of disease to humans from pathogenic organisms. Contamination from bacteria is the number one reason for listing streams on Virginia's Impaired Waters List. As a result, bacteria Total Maximum Daily Load (TMDL) studies are common in Virginia. Monitoring results indicate 12% of Virginia streams are above the interim standard of 400 colony forming units (CFU) of fecal coliform bacteria per 100 milliliters of water. Throughout the Commonwealth, TMDL implementation plans are focused on reducing bacteria in impaired watersheds. ProbMon will help track improvement on a state-wide basis.



Peak Creek in Pulaski, Virginia flows past a major industrial site. The photo above shows the site in 1989.

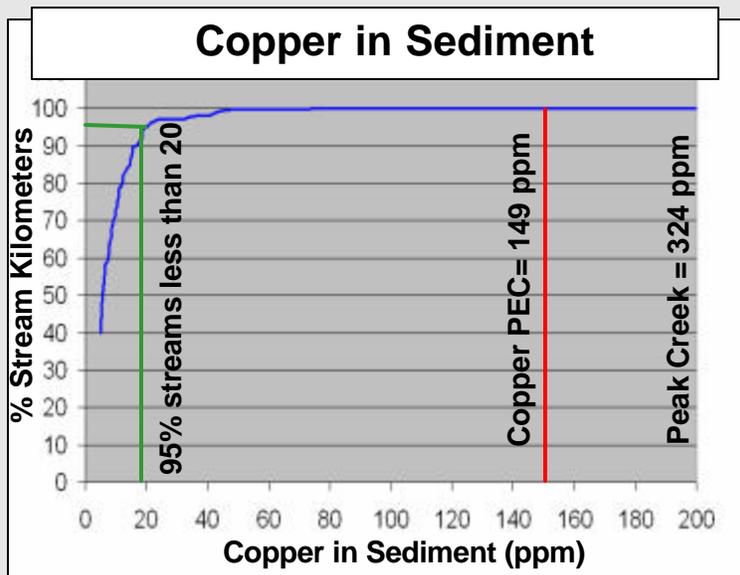
ESTABLISH BASELINE DATA

Sediment Contamination

Relative bed stability is used by VDEQ in order to determine the quantity of sediments in streams. However, stream sediment quality is important because stream sediments can become contaminated with toxic chemicals and heavy metals. While sediment contamination is a well known problem, sediment contamination criteria have not been established. One of the proposed uses of ProbMon's data is to establish baseline data to improve VDEQ's understanding of natural levels of contaminants in sediment. This will help VDEQ differentiate between natural and contaminated sediments and aid in prioritizing sites with sediment contamination problems for remediation.

Elevated Metal Case Study

The graph on the right illustrates the statewide distribution of copper in sediments. Ninety-five percent of stream kilometers in Virginia have sediment copper concentration of less than 20 parts per million (ppm). Peak Creek, in Pulaski, Virginia, receives drainage from an abandoned industrial facility (currently being cleaned up). The sediment copper concentrations were higher in Peak Creek than any other stream VDEQ has sampled in the ProbMon program. In Virginia, Peak Creek was the only station above the probable effect concentration (PEC) for copper. PEC values are used to predict the likelihood of sediment toxicity, but are not water quality standards. In the absence of sediment metal standards, VDEQ is able to compare these numbers to regional and statewide distributions in order to establish if a stream has elevated levels of metals in the sediment.

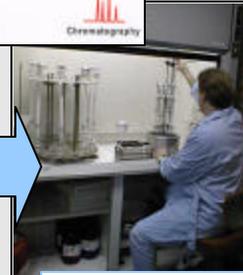
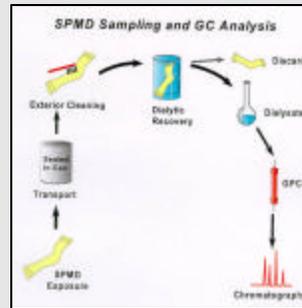
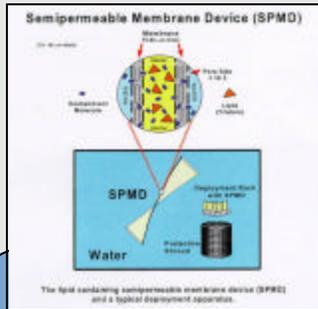


Innovative Monitoring Practices

In 2003, VDEQ collected data to assess water column toxicity at 41 ProbMon stations using Semi-permeable Membrane Devices (SPMDs) or “Virtual Fish.” This work was accomplished through a grant from the USEPA and chemical analyses was conducted by the United States Geological Survey (USGS). Each device consisted of five ribbon like polyethylene tubes filled with a synthetic fish oil suspended within a small cage. They were left in the stream for at least 30 days to accumulate any potential dissolved organic chemicals.

Typically, detection of toxic compounds is from the analysis of sediment and fish tissue and not by direct measurement of water column concentrations. SPMDs simulate the uptake of contaminants by fish.

VDEQ Staff prepare SPMDs for deployment



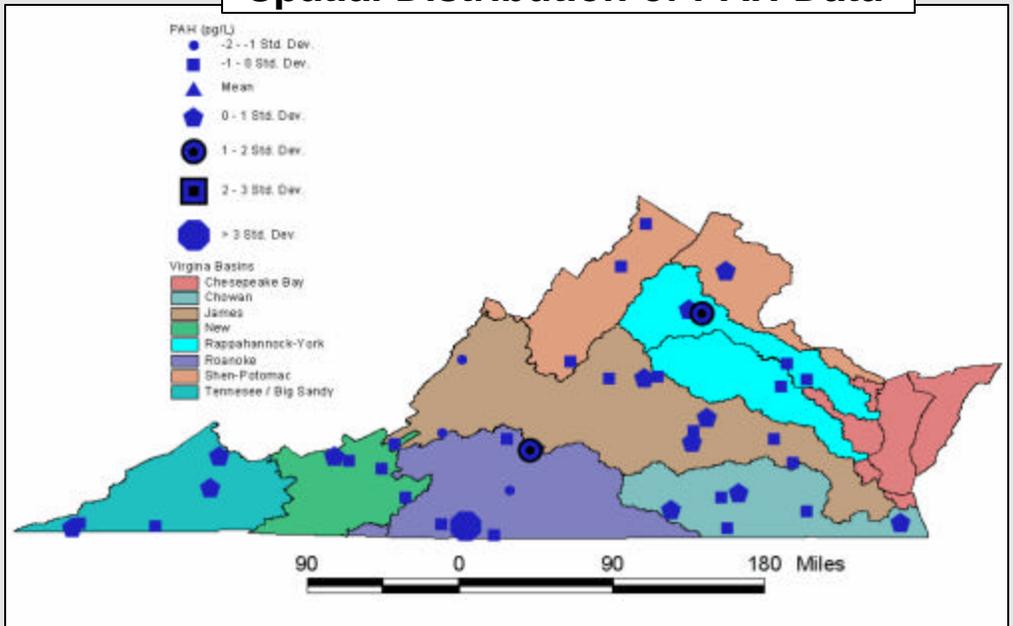
USGS Staff analyze SPMD data

The difficulty to government agencies in making direct measurements of toxic chemicals is the high cost of analytical methods. Nevertheless, VDEQ is required by the Federal Clean Water Act and the Virginia Water Quality Monitoring, Information, and Restoration Act to monitor all state waters for all compounds with water quality standards.

To meet these requirements, the VDEQ deployed SPMD samplers at ProbMon sites in order to collect data for a subclass of toxic compounds. This is the first time that concentrations of trace toxic compounds have been measured on a statewide geospatial scale. The map on the right shows the distribution of Polycyclic Aromatic Hydrocarbons (PAH) by major river basin. The mean (or average) concentration is depicted with the triangle. The smaller shapes show concentrations that are varying degrees less than the mean while the larger shapes are higher concentrations than the mean. PAH are formed when organic materials, like coal, are not completely burned.

Due to the random sample design incorporated by ProbMon, VDEQ was able to conduct a thorough analysis of the SPMD data. VDEQ determined the occurrence and distribution of 67 toxic compounds of which 28 have associated water quality standards. The results of the SPMD data indicate that all of the organic compounds included in the analysis met state water quality standards except for Polychlorinated Biphenyls (PCBs). Results estimate that 2% of Virginia streams exceed the state water quality standard of 1700 parts per quadrillion for PCBs. PCBs were traditionally used as coolants in electrical transformers and were banned in 1977.

Spatial Distribution of PAH Data



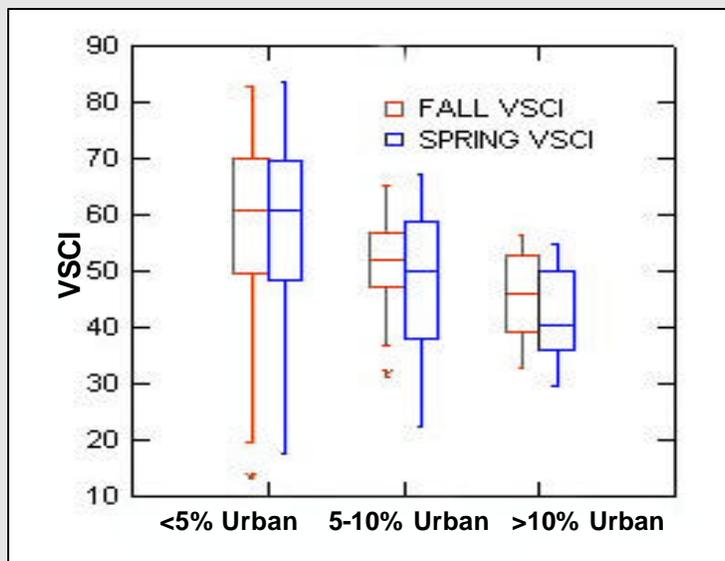
Future Goals

GIS ANALYSIS

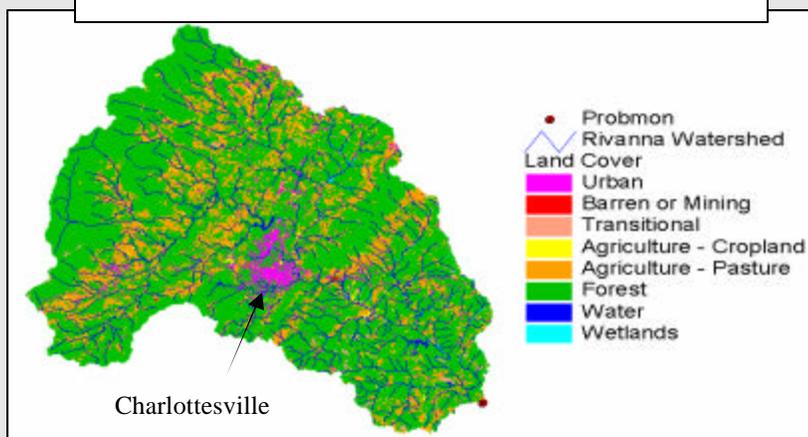
Watershed delineations using Geographic Information System (GIS) is being employed to determine the amount and types of land cover in the watersheds upstream of all ProbMon monitoring stations. This data can be used to relate landscape information to water chemistry, biological communities, and habitat conditions. The box plot on the right indicates that with increasing urbanization median VSCI values decline.

GIS Information Generated for ProbMon Sites:

- ✓ Watershed Area
- ✓ Watershed Land Cover
- ✓ Riparian Land Cover
- ✓ Average Rainfall (30 year average)
- ✓ Average Rainfall (year sampled)
- ✓ Average % Slope
- ✓ Road Crossing Density
- ✓ Road Length
- ✓ Elevation



Land Cover Rivanna River Watershed



ProbMon Goals

- ◆ Report on 100% of Virginia's freshwater resources
- ◆ Describe natural condition gradient (reference conditions)
- ◆ Establish current statewide baseline condition
- ◆ Describe how this baseline changes over time
- ◆ Identify common stressors and pollutants in Virginia
- ◆ Identify which stressors and pollutants pose the greatest risk
- ◆ Develop and implement new monitoring capabilities
- ◆ Provide policy makers with accurate resource characterization



For more information on Virginia's Probabilistic Monitoring Program, contact Jason Hill with VDEQ at 540- 562-6700 or email jrhill@deq.virginia.gov, or search the DEQ website at <http://www.deq.virginia.gov/probmon/>.