# *Connecting conservation practices to local stream health in the Chesapeake Bay watershed*




## USGS-VT Stream Team:

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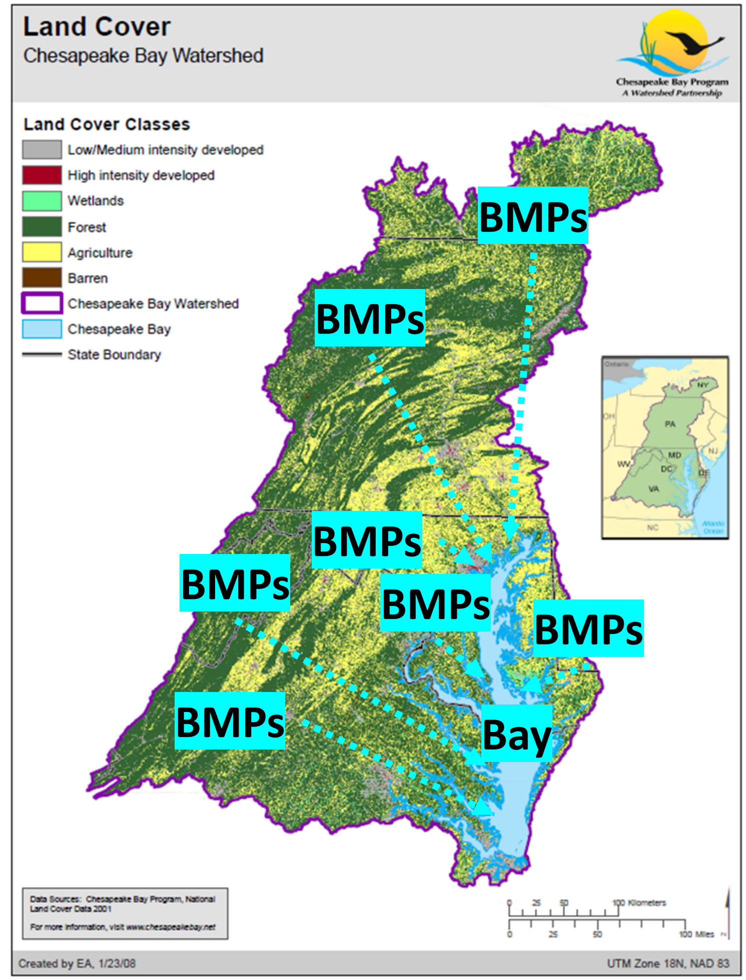
U.S. Department of the Interior
U.S. Geological Survey

# *What are the co-benefits of Chesapeake watershed BMPs?*

The Chesapeake Bay Partnership is implementing **conservation practices (CP**; e.g. BMPs) throughout the Chesapeake Watershed to reduce nutrient and sediment delivery to the Bay.

This study aims to provide an integrated and detailed understanding of **how local streams respond** to these management efforts

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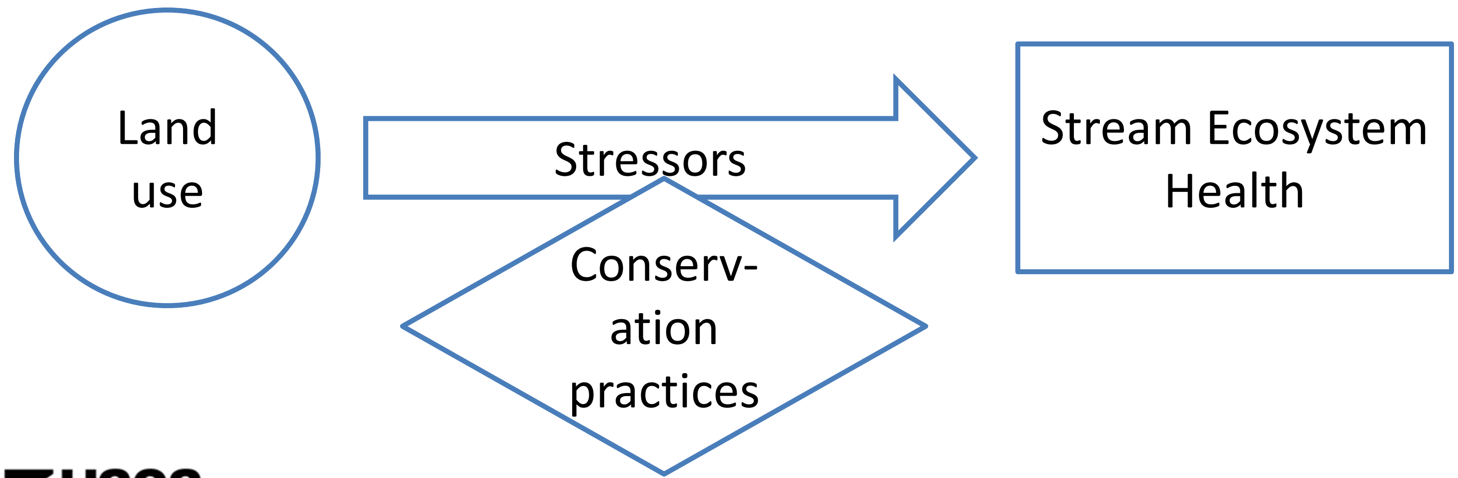
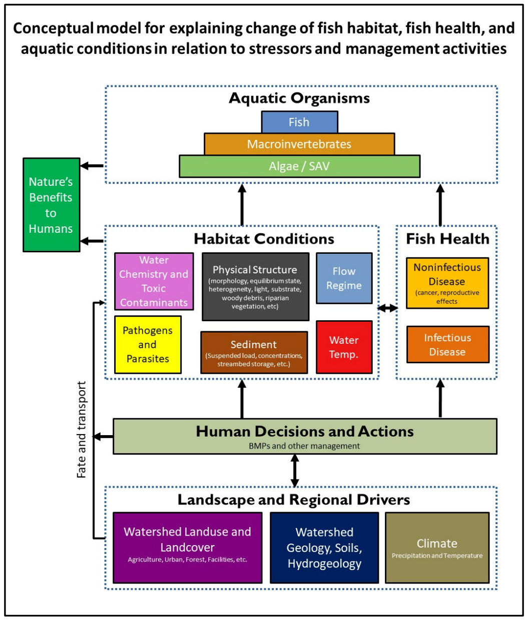
# *Critical unknowns*

- How do CPs change water quality and the stressors that impact stream aquatic life?
- Which CPs improve stream health more effectively?

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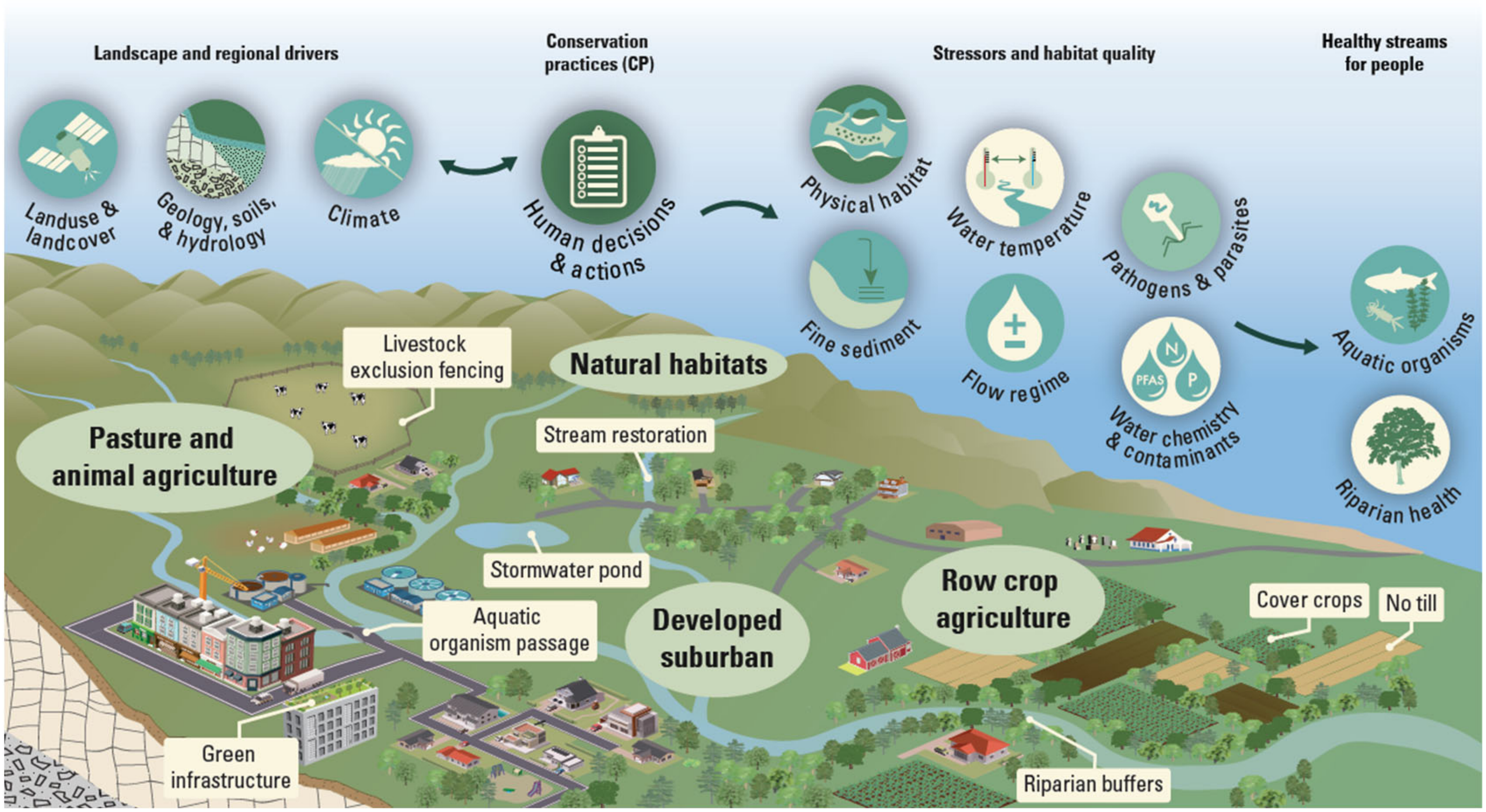
# *Connecting conservation practices and healthy streams*

This work will determine both how streams are influenced by the **land use in their watersheds** and whether **conservation practices and management** are improving their condition through reducing the **stressors** to stream aquatic and riparian **ecosystem health**.

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# *Critical knowledge to be delivered to stakeholders*

- Effects of CPs on local water-quality conditions
- Degree that these same CPs also provide local stream ecosystem benefits
- Deeper understanding of local stream ecosystems, including stressors and CPs, to guide selection of management efforts that enhance both water-quality and overall stream ecosystem health

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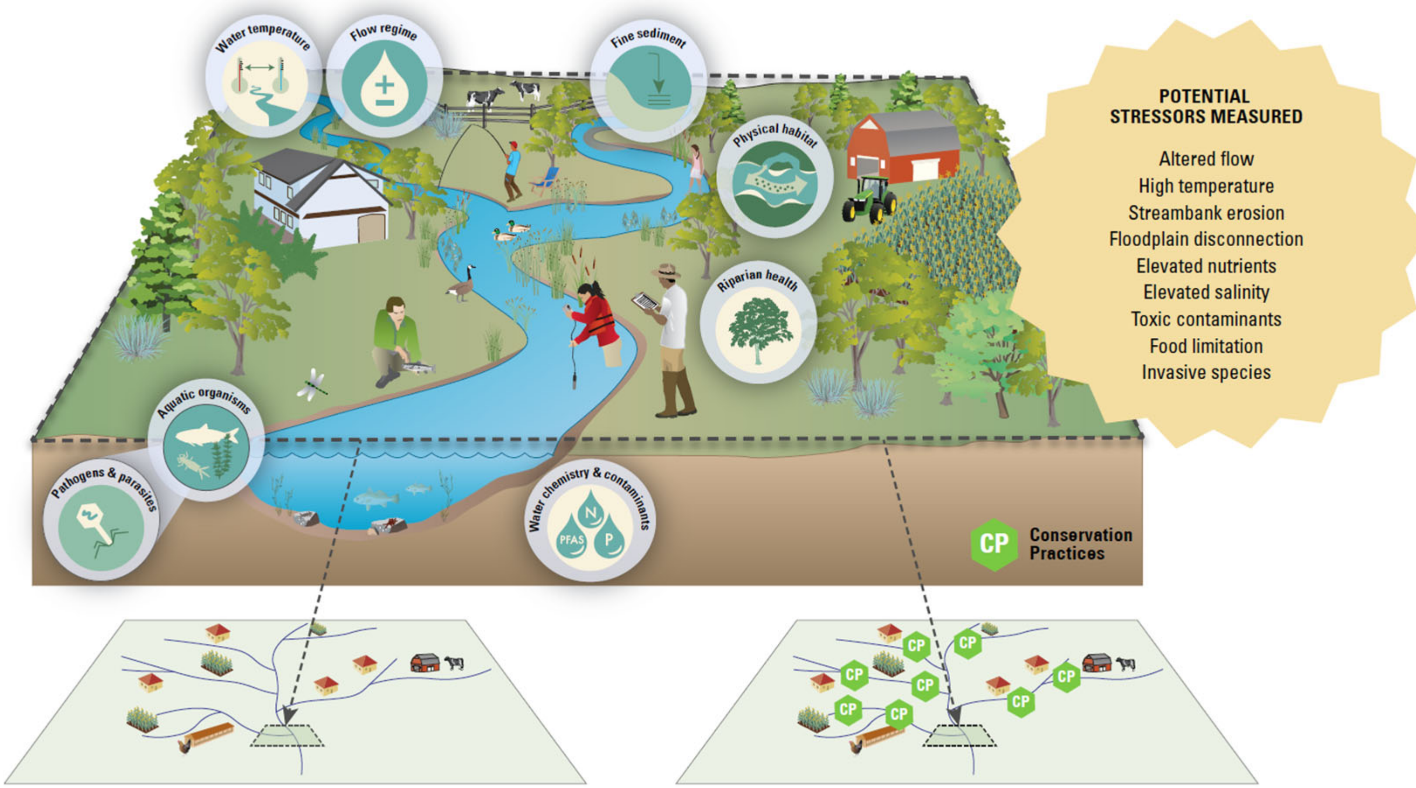
# *Holistic approach*

This study measures many aspects of stream ecosystem health, including stressors to stream life, and landscape characteristics, in each of many Chesapeake streams with contrasting amounts of **upstream** conservation practices and intensive land use.

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# *Analytical and sampling approach*

Sites selected along both LU and BMP spatial gradients

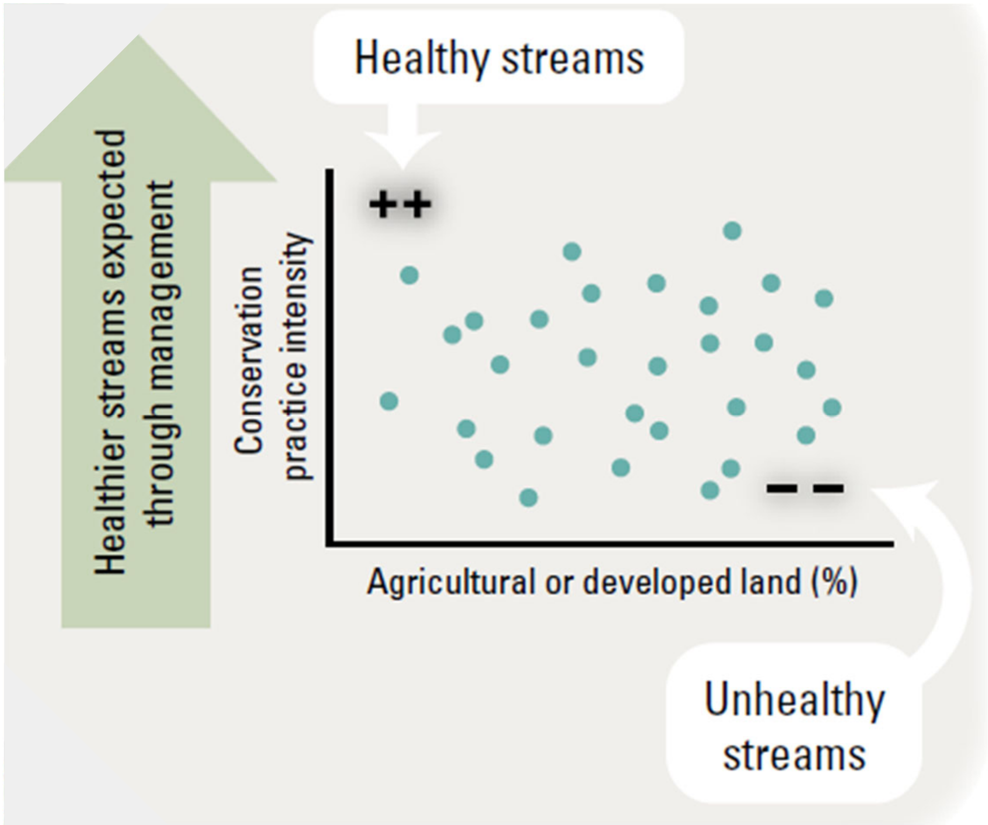
Large **SPATIAL** replication

Very controlled site selection to minimize and account for other influences (like physiography and hydrogeology)

Measure drivers and stressors and responses

Same methods everywhere

→ **Reduce noise to detect signal & attribute causes**

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# *Stream choice*

This study focuses on the following important Chesapeake landscapes for assessment of 30 streams over a one-year period:

> Pasture in the Shenandoah Valley (2021),
> Row crop in Delmarva (2022),
> Mixed agriculture in PA and MD Piedmont (2023),
> Developed MD-DC-VA Piedmont (2024)

**Streams between 15 to 50 km² drainage area**, similar hydrogeology/LU setting within typology other than primary LU gradient

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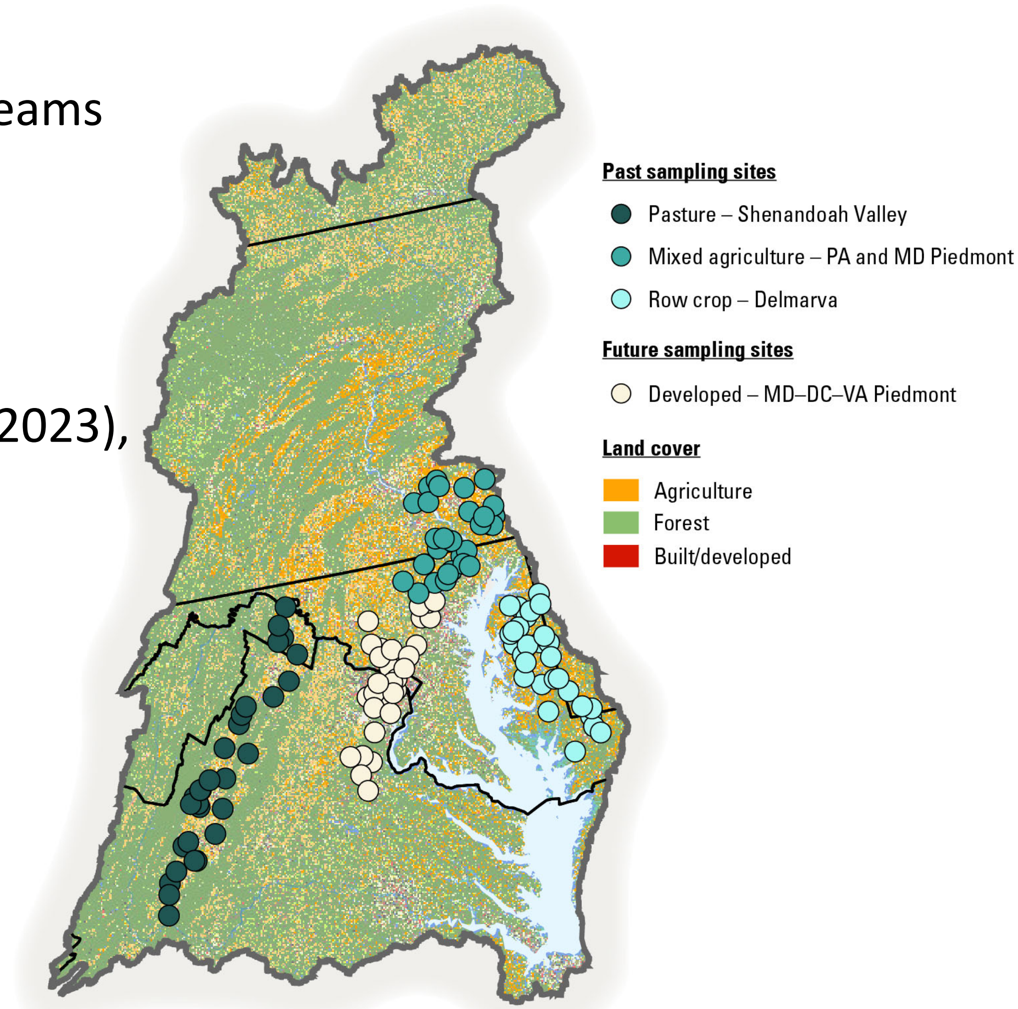
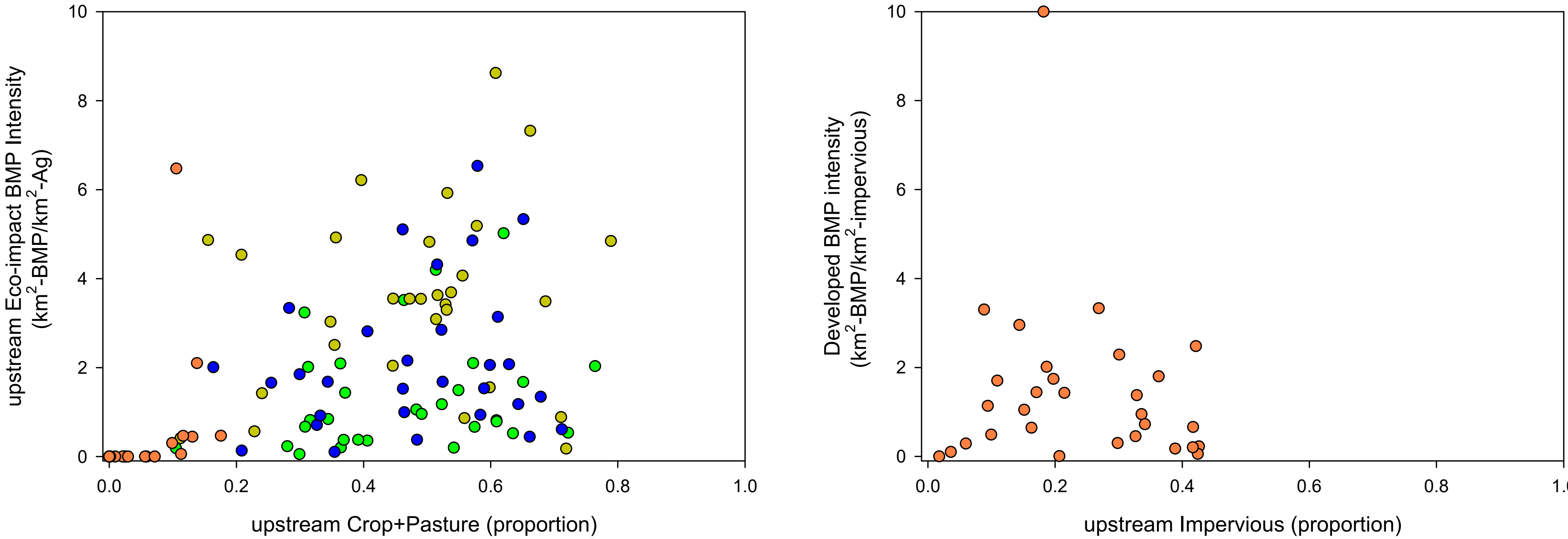


# *Site sampling gradients*

Sites selected along both LU and BMP-intensity gradients




**Shenandoah Valley pasture**
**Delmarva row crop**
**PA-MD Piedmont mixed agriculture**
**MD-DC-VA Piedmont developed**

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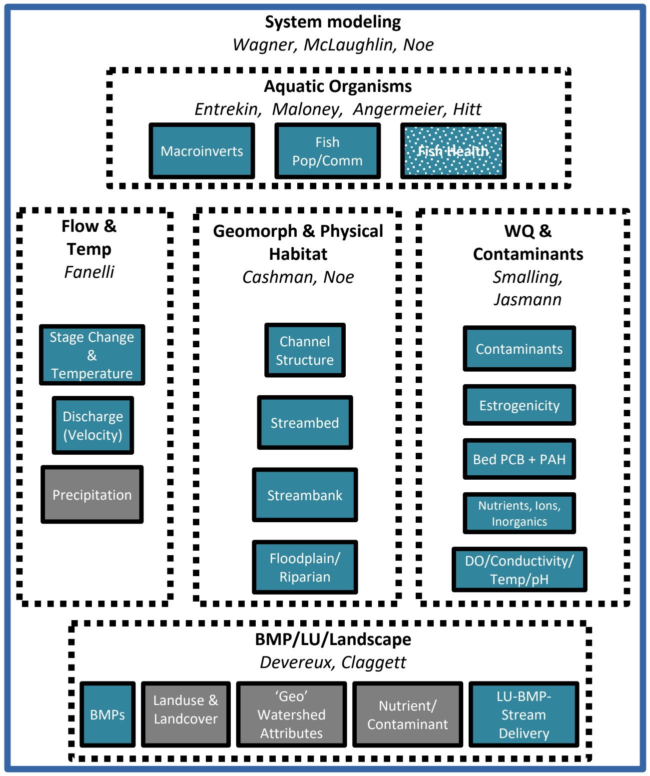
# *What we measure at each stream*

Many ecosystem health, stream-riparian characteristics, and potential stressor metrics:




WQ + Contaminants (twice baseflow): 78
Channel Geomorph + Habitat: 63
Stage + Temp: 24

Macroinverts: 17
Fish: 42
Riparian: 19

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# *Challenges*

- Obtaining landowner permissions for accessing multiple properties for 30 streams, each year
- A lot of field and lab work
- Using BMP data is inordinately complicated
- Geospatial processing and analysis of all data

# *Key challenge of effectively using BMP data*

We use the USDA NRCS/FSA dataset of BMPs implemented (through the USDA-USGS Section 1619 [privacy] agreement): 198 different practices in Stream Team agricultural watersheds

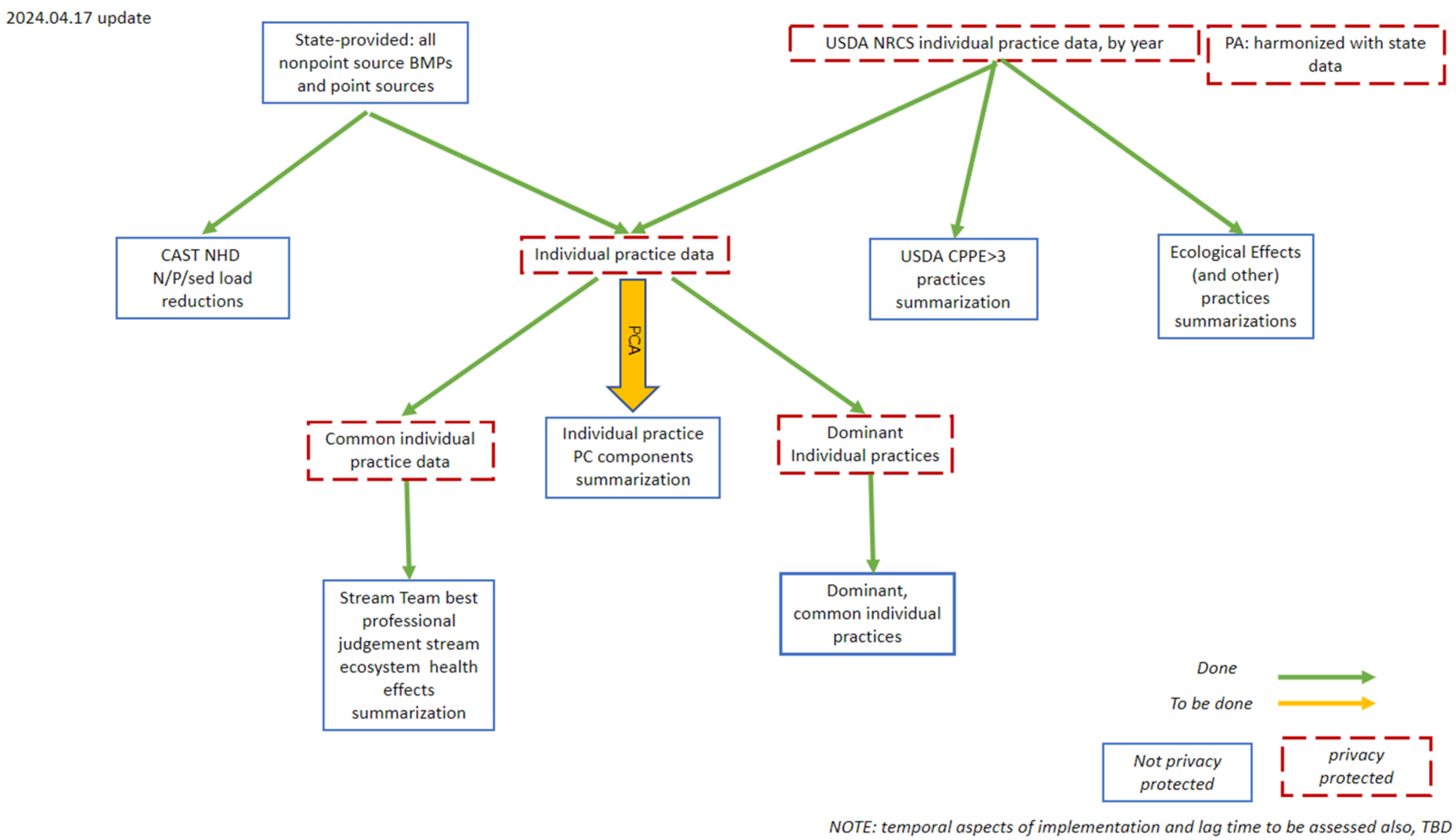
And the CBP NEIEN dataset: 124 different practices

| Row Labels |
|---|
| Access Control |
| Access Road |
| Acquisition Process - Appraisal Technical Review First Review |
| Acquisition Process - Appraisal Technical Review Second Review |
| Acquisition Process - Environmental Database Records Search |
| Adding food-producing trees and shrubs to existing plantings |
| Advanced Automated IWM - Year 2-5, soil moisture monitoring |
| Agrichemical Handling Facility |
| Agricultural Energy Management Plan - Written |
| Agricultural Energy Management Plan, Headquarters - Written |
| Amending Soil Properties with Gypsum Products |
| Amendments for Treatment of Agricultural Waste |
| Anaerobic Digester |
| Animal Mortality Facility |
| Apply controlled release nitrogen fertilizer |
| Apply split applications of nitrogen based on a pre-sidedress nitrogen test on cropland |
| Brush Management |
| Clipping mature forages to set back vegetative growth for improved forage quality |
| Combustion System Improvement |
| Composting Facility |
| Comprehensive Nutrient Management Plan |
| Comprehensive Nutrient Management Plan - Applied |
| Conservation Completion Incentive Second Year |
| Conservation Cover |
| Conservation cover to provide cover and shelter habitat for pollinators and beneficial insects |
| Conservation cover to provide habitat continuity for pollinators and beneficial insects |
| Conservation Crop Rotation |
| Continuous cover crops |
| Contour Buffer Strips |
| Contour Farming |
| Cover Crop |
| Cover crop to minimize soil compaction |
| Cover crop to minimize soil compaction |
| Cover crop to reduce water quality degradation by utilizing excess soil nutrients |
| Cover crop to reduce water quality degradation by utilizing excess soil nutrients-surface water |
| Critical Area Planting |
| Cropland conversion to grass for soil organic matter improvement |
| Deep Tillage |
| Denitrifying Bioreactor |

| Row Labels | Count of CAST_AMOUNT |
|---|---|
| Biofiltration | 53 |
| Bioretention | 7874 |
| Bioswale | 694 |
| Cisterns & Rain Barrels | 370 |
| Conservation Landscaping Practices | 1751 |
| Constructed Wetland | 116 |
| D&G Road - Outlets Only | 1 |
| D&G Road - Surface Aggregate and Raised Roadbed | 547 |
| Disconnection of Rooftop Runoff | 3270 |
| Dry Detention Ponds | 4761 |
| Dry Detention Ponds & Hydrodynamic Structures | 7467 |
| Dry Extended Detention Ponds | 5481 |
| Dry Swale | 1941 |
| Dry Well | 8102 |
| Erosion and Sediment Control Level 2 | 578 |
| Filter Strip | 222 |
| Filtering Practices | 4537 |
| Filtration | 111 |
| Floating Treatment Wetland 1 | 7 |
| Floating Treatment Wetland 2 | 1 |
| Floating Treatment Wetland 3 | 1 |
| Floating Treatment Wetland 4 | 1 |
| Green Roofs | 1805 |
| Impervious Disconnection | 77 |
| Infiltration Basin | 210 |
| Infiltration Practices | 3888 |
| Infiltration Trench | 1046 |
| Narrow Urban Forest Buffer | 15 |
| New Runoff Reduction | 38993 |
| New Stormwater Treatment | 6613 |
| Permeable Pavement | 1644 |
| Rain Garden | 565 |
| Reduction of Impervious Surface | 1437 |
| Retrofit Runoff Reduction | 13558 |
| Retrofit Stormwater Treatment | 218 |
| Storm Drain Cleaning | 991 |
| Street Cleaning Practice 1 | 3 |
| Street Cleaning Practice 10 | 2 |

# Key challenge of effectively using BMP data

We are evaluating the utility of multiple different approaches to summarizing BMP data

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# *BMP expected effects: expert elicitation*

Stream Team experts ranked the total (direct + indirect, intended and unintended) expected effects of each dominant BMP type on stream metric responses:

| Chesapeake BMP names | Agriculture or Developed sectors | Hydrology | Hydrology | Hydrology | Water Temperature | Water Temperature | Water Temperature | Nitrogen | Nitrogen | Nitrogen | Phosphorus | Phosphorus | Phospl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BMP name | Ag or Urban | Effects Score | Confidence | Comment | Effects Score | Confidence | Comment | Effects Score | Confidence | Comment | Effects Score | Confidence | Comm |
| Access Control | Ag | 1 | 2 | less soil comp | 0 | 1 | | 1 | 2 | | 2 | 2 | less so |
| Amendments for Treatment of Agricultural Waste | Ag | 0 | 3 | | 0 | 3 | | 1 | 1 | only strongly b | 2 | 2 | binders |
| Apply enhanced efficiency fertilizer products | Ag | 0 | 3 | | 0 | 3 | | 3 | 2 | | 2 | 2 | |
| Apply nutrients no more than 30 days prior to planned planting da | Ag | 0 | 3 | | 0 | 3 | | 2 | 2 | | 2 | 2 | |
| Aquatic Organism Passage | Ag | 1 | 1 | | 0 | 1 | | 0 | 2 | | 0 | 2 | |
| Brush Management | Ag | -1 | 1 | increase throu | -2 | 1 | remove shadin | 0 | 1 | | -1 | 1 | |
| Clearing and Snagging | Ag | -1 | 2 | increase down | -1 | 2 | remove shadin | -1 | 2 | increase down | -1 | 2 | |
| Conservation Cover | Ag | 2 | 2 | | -1 | 1 | Herbaceous er | 3 | 3 | | 3 | 3 | |
| Conservation Crop Rotation | Ag | 0 | 1 | | 0 | 1 | | 1 | 2 | Alternating cro | 1 | 2 | Alterna |
| Continuous cover crops | Ag | 1 | 1 | Promote soil ir | 1 | 0 | Infiltration dur | 2 | 2 | More soil N im | 2 | 2 | less so |
| Cover Crop | Ag | 1 | 1 | Promote soil ir | 1 | 0 | Infiltration dur | 1 | 2 | | 2 | 2 | |
| Dike and Levee | Ag | -3 | 2 | Depends on wi | -1 | 2 | prevents infiltr | -2 | 2 | | -2 | 2 | |
| Energy Efficient Building Envelope | Ag | 0 | 3 | No effect on st | 0 | 3 | No effect on st | 0 | 3 | No effect on st | 0 | 3 | No effe |
| Enhancement - Energy Management | Ag | 0 | 1 | | 0 | 1 | | 0 | 1 | | 1 | 1 | |
| Enhancement - Nutrient Management | Ag | 0 | 2 | | 0 | 2 | | 2 | 2 | | 2 | 2 | |
| Enhancement - Pest Management | Ag | 0 | 2 | | 0 | 2 | | 0 | 2 | | 0 | 2 | |

hydrology, water temperature, nitrogen, phosphorus, sediment, contaminants, in-channel physical habitat, riparian, fish, macroinvertebrates, and 'whole' ecosystem.

# *Key challenges of geospatial processing*

Geospatial covariate datasets are numerous and disparate

A lot is available, but not everything we would want

Weighting for distance from sampling point

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# *Engagement*

Results of the study will be communicated to stakeholders and landowners through several approaches:

- Data releases published prior to written products
- Creating a website to map and display our measurements in each stream compared to the other streams in each Chesapeake landscape
- Engaging in discussions with local, state, and federal governments, nonprofits, and landowners to share findings and provide insights on connections between CP adoption and stream health
- Publishing of findings in scientific literature so other regions around the country can learn from the Chesapeake and apply to their local streams


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## *Timeline*

# *ENGAGEMENT*

| Landscape | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|
| Shenandoah | field | | data | write | | |
| Delmarva | | field | data | write | | |
| PA/MD | | | field | data | write | |
| Developed | | | | field | data | write |
| *BMP* | | | data | data | write | |
| *Synthesis* | | | | | analyze | write |

USGS Fact Sheet on goals & approach is close to publication

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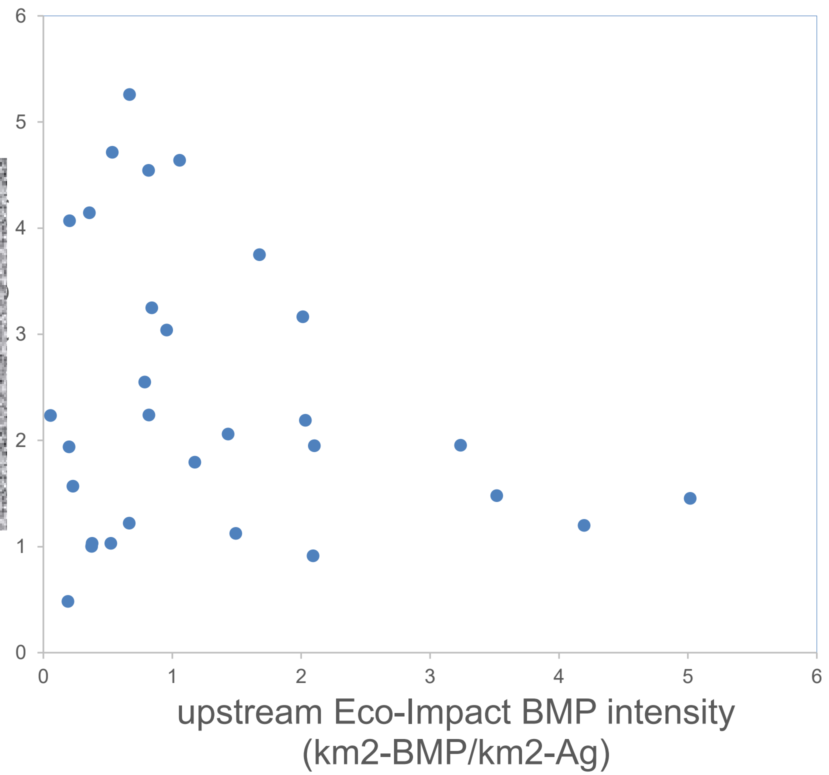
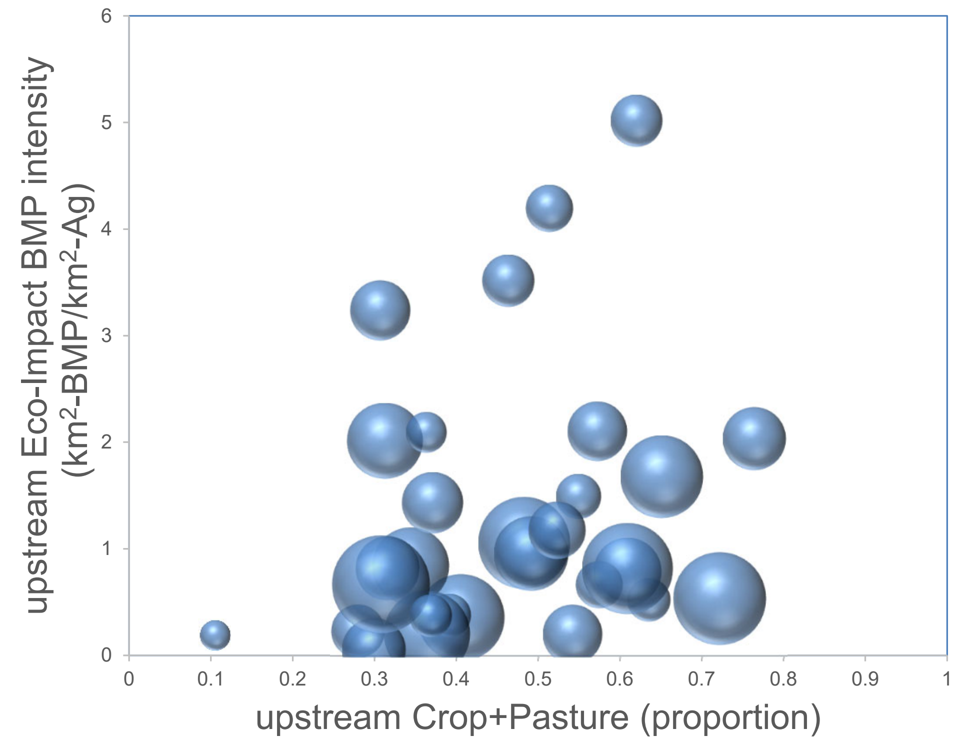
# *Early view of some Shenandoah data*

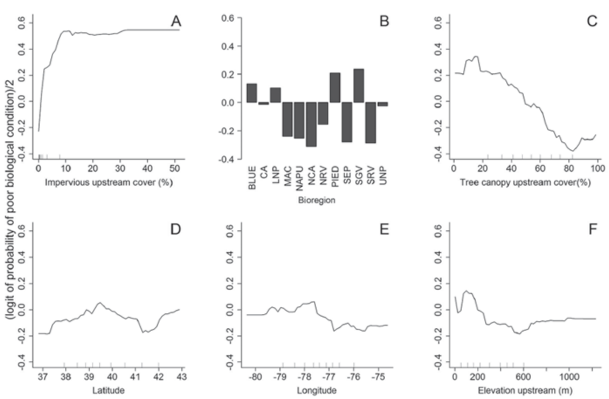
Pattern of less stream [illegible] downstream of most intensive BMP implementation?



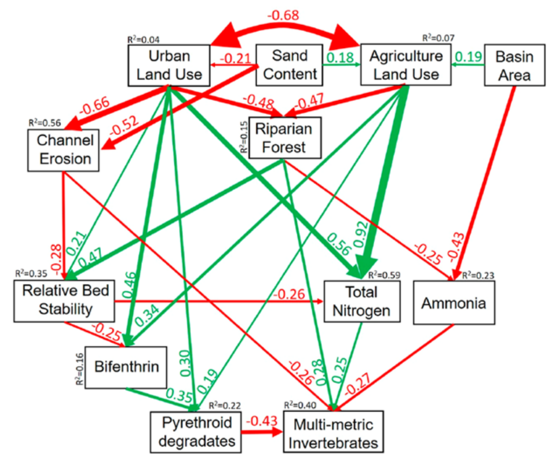
# Statistical approach possibilities

## Machine learning regression



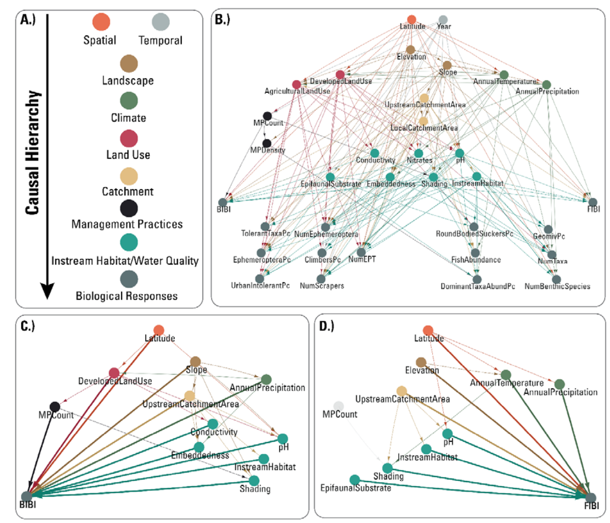

Maloney et al. 2018

## Structural equation model




Schmidt et al. 2019

## Bayesian network learning




Emmons et al. in revision

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*Need to disentangle and attribute causation among multiple drivers and stressors*

# *Thanks*









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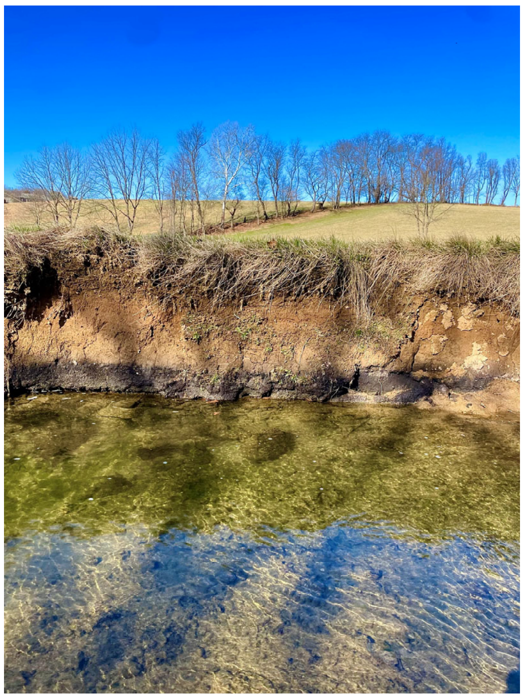
# *Acknowledgements*



This study would not have been possible without the generous support of private, nonprofit, and public landowners to access and study their streams and riparian areas.
*We are sincerely grateful for their generosity.*

Numerous stakeholders charged with implementing CPs have helped us connect with these people and to better understand local stream issues and their information needs for better management of their watersheds.

This work is supported by USGS Chesapeake Bay Activities and is a partnership between USGS and Virginia Tech.

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University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
INTEGRATION AND APPLICATION NETWORK

# *Lists of measurements*

## Water quality + Contaminants:

| Group | Abb. | Analyte |
|---|---|---|
| Estrogenicity | Estrogenicity | Estrogenicity |
| Toxics | Contaminants | Aquatic Hazards method |
| Toxics | PFAS | PFAS |
| Toxics | PCBs | PCBs |
| Toxics | PAHs | PAHs |
| Field Parameters | WT | Temperature, water, degrees Celsius |
| Field Parameters | SC | specific conductance |
| Field Parameters | pH | pH |
| Field Parameters | DO | Dissolved oxygen |
| Field Parameters | TB | Turbidity |
| Nutrients | TN | Total nitrogen (NH3+NO2+NO3+Organic), unfiltered |
| Nutrients | TDN | Total nitrogen (NH3+NO2+NO3+Organic), filtered |
| Nutrients | NO3 | nitrogen, nitrite + nitrate |
| Nutrients | NO2 | nitrogen, nitrite |
| Nutrients | NH3 | Nitrogen, ammonia |
| Nutrients | ON | Organic nitrogen, water, unfiltered, milligrams per liter |
| Nutrients | DON | Organic nitrogen, water, filtered, milligrams per liter |
| Nutrients | TP | Phosphorus |
| Nutrients | TDP | Phosphorus |
| Nutrients | OP | phosphorus, phosphate, ortho |
| Misc. Inorganics | TDS | Solids, Residue on Evaporation (ROE) at 180 deg C, dissolved, gravimetric (TDS) |
| Major Ions | ALK | Alkalinity, laboratory |
| Major Ions | Cl | Chloride |
| Major element | Ca | Calcium |
| Major element | Mg | Magnesium |
| Major element | K | Potassium |
| Major element | Si | Silica |
| Major element | Na | Sodium |
| Major element | S | Sulfur |
| Minor anion | Br | Bromide |
| Minor anion | SO4 | Sulfate |

| | | |
|---|---|---|
| Trace element | Al | Aluminum |
| Trace element | Sb | Antimony |
| Trace element | As | Arsenic |
| Trace element | Ba | Barium |
| Trace element | Be | Beryllium |
| Trace element | Bi | Bismuth |
| Trace element | B | Boron |
| Trace element | Cd | Cadmium |
| Trace element | Ce | Cerium |
| Trace element | Cs | Cesium |
| Trace element | Cr | Chromium |
| Trace element | Co | Cobalt |
| Trace element | Cu | Copper |
| Trace element | Dy | Dysprosium |
| Trace element | Er | Erbium |
| Trace element | Eu | Europium |
| Trace element | Gd | Gadolinium |
| Trace element | Ga | Gallium |
| Trace element | Ho | Holmium |
| Trace element | Fe | Iron |
| Trace element | La | Lanthanum |
| Trace element | Pb | Lead |
| Trace element | Li | Lithium |
| Trace element | Lu | Lutetium |
| Trace element | Mg | Manganese |
| Trace element | Mo | Molybdenum |
| Trace element | Nd | Neodymium |
| Trace element | Ni | Nickel |
| Trace element | P | Phosphorus |
| Trace element | Pr | Praseodymium |
| Trace element | Ru | Rubidium |
| Trace element | Sa | Samarium |
| Trace element | Se | Selenium |
| Trace element | Sr | Strontium |
| Trace element | Te | Tellurium |
| Trace element | Tb | Terbium |
| Trace element | Tl | Thallium |
| Trace element | Th | Thorium |
| Trace element | Tm | Thulium |
| Trace element | Ti | Titanium |
| Trace element | W | Tungsten |
| Trace element | U | Uranium |
| Trace element | V | Vanadium |
| Trace element | Yb | Ytterbium |
| Trace element | Y | Yttrium |
| Trace element | Zn | Zinc |
| Trace element | Zr | Zirconium |

| Stressor Sources | Chemical Class | Chemical Indicator / Stressor | Partner Compound |
|---|---|---|---|
| Agriculture | Herbicide (in use) | Atrazine | Atrazine-desethyl (degradate) |
| Agriculture | Herbicide (in use) | Metolachlor | Metolachlor-ESA (degradate) |
| Agriculture | Insecticide (in use) | Fipronil | Fipronil desulfinyl (degradate) |
| Agriculture | Insecticide (neonic in use) | Clothianidin (treats corn seed) | A degradate? |
| Agriculture Livestock | Antibiotic in animal feed | Sulfamethazine or Monensin ? | ? surrogate chemical in feed? |
| Agriculture / Industry | Phytoestrogen (isoflavone) | Daidzein, Equol,... etc. | Genistein, Coumestrol,...etc. |
| Domestic WW (HPCPs) | Artificial sweetener | Sucralose | |
| Domestic WW (HPCPs) | Antimicrobial | Triclosan | Methyltriclosan (degradate)... or Triclocarban instead |
| Domestic WW / Medical | Anticonvulsants | Carbamazepine | Lamotrigine (Clonazepam) |
| Domestic WW (HPCPs) | Antidepressant | Venlafaxine | Desvenlafaxine |
| Domestic WW / Medical | Diabetes, high blood sugar | Metformin | |
| Domestic WW (HPCPs | Antihistamine | Fexofenadine | |
| Biogenic / Domestic WW | Endogenous sex hormone | Estradiol (E2) | Estrone (E1, oxidized product) |
| Biogenic / Domestic WW | Endogenous sterol, hormone precursor | Cholesterol | 5-B-Coprostanol (biohydrogenation degradate) |
| Domestic WW (HPCPs) / Industrial | Musk fragrance | Galaxolide (HHCB) | Galaxolide lactone (degradate) |
| Domestic WW (HPCPs) / Industry | Surface protectors, surfactants, AFFFs | Perfluorooctanoic acid (PFOA) | Perfluorooctane sulfonic acid (PFOS) |
| Domestic WW (HPCPs) / Industry | Surface protectors, surfactants, AFFFs | Perfluorobutanoic acid (PFBA) | Perfluorohexanoic acid (PFHxA) |
| Industry / Domestic WW (HPCPs) | Solvent enhancers | 1,4-Dioxane (chlorinated solvent stabilizer, HPCP solvent) | 5-methyl-1H-benzotriazole (drug precursor, anticorrosion |
| Industry / Mining / Urban | Flame retardants, plasticizers, + other uses | Tributylphosphate (also mining extractant, aircraft fluid) | Bisphenol A |
| Natural / Climate | Wildland Fire Tracers | Levoglucosan | Galactosan, Mannosan (stereoisomers) |

# *Lists of measurements*

Stage + Temp:

| Parameter | Metric Name | Description |
|---|---|---|
| Stage | frequency_runoff | Number of runoff events divided by the number of days in the period of record. |
| Stage | frequency_XX_pct | Number of events exceeding XXth percentile stage divided by number of days in the period of record. |
| Stage | cv_daily | Coefficient of variation of mean daily stage throughout the period of record. |
| Stage | cv_hourly | Coefficient of variation of mean hourly stage throughout the period of record. |
| Stage | cv_5min | Coefficient of variation of 5-minute stage throughout the period of record. |
| Stage | skew_daily | Skewness coefficient of mean daily stage throughout the period of record. |
| Stage | skew_hourly | Skewness coefficient of mean hourly stage throughout the period of record. |
| Stage | skew_5min | Skewness coefficient of 5-minute stage throughout the period of record. |
| Stage | flashiness_daily | Flashiness index of mean daily stage throughout the period of record. |
| Stage | flashiness_hourly | Flashiness index of mean hourly stage throughout the period of record. |
| Stage | flashiness_5min | Flashiness index of 5-min stage throughout the period of record. |
| Stage | runoff_threshold_7day | Estimated depth of rainfall (accumulated over 7-day window) that causes runoff response. |
| Stage | runoff_threshold_3day | Estimated depth of rainfall (accumulated over 3-day window) that causes runoff response. |
| Stage | runoff_threshold_2day | Estimated depth of rainfall (accumulated over 2-day window) that causes runoff response. |
| Temperature | frequency_20c | Number of days when water temperature exceeded 20-degrees C divided by number of days in the period of record. |
| Temperature | frequency_25c | Number of days when water temperature exceeded 25-degrees C divided by number of days in the period of record. |
| Temperature | duration_20c | Total duration when water temperature exceeded 20-degrees C divided by duration of the period of record. |
| Temperature | duration_25c | Total duration when water temperature exceeded 25-degrees C divided by duration of the period of record. |
| Temperature | mean_daily_max | Mean of daily maximum water temperatures throughout the period of record. |
| Temperature | mean_daily_range | Mean of daily maximum minus minimum water temperatures throughout the period of record. |
| Temperature | max_weekly_mean | Maximum of 7-day moving-average daily mean water temperature throughout the period of record. |
| Temperature | cv_daily_mean | Coefficient of variation of mean daily water temperature throughout the period of record. |
| Temperature | cv_daily_max | Coefficient of variation of maximum daily water temperature throughout the period of record. |
| Temperature | thermal_sensitivity | Slope of the linear regression comparing mean daily air temperature and mean daily water temperature. |

# *Lists of measurements*

## Geomorphic + Habitat:

| Parameter | Metric Name | Description |
|---|---|---|
| In Channel Habitat | In_Channel_CC | Mean canopy cover for the channel of study area. |
| In Channel Habitat - Planform | Channel_Width_Mean | Mean width of study reach channel. |
| In Channel Habitat - Planform | Channel_Width_SD | Standard deviation of width of study reach. |
| In Channel Habitat - Planform | Channel_Width_CoV | Coefficient of Variance for channel width for study reach. |
| In Channel Habitat - Substrate | Peb_D50 | Median pebble count size (D50) of the study reach. |
| In Channel Habitat - Substrate | Peb_Het | Heterogeneity (D84/D50) of the pebble count of the study reach. |
| In Channel Habitat - Substrate | Peb_Het2 | Heterogeneity2 (D10/D60) of pebble count of the study reach. |
| In Channel Habitat - Substrate | Peb_Sorting | Standard deviation of distribution of pebble count for the study reach. |
| In Channel Habitat - Substrate | Peb_Kurt | Pebble count peakedness of distribution. |
| In Channel Habitat - Substrate | Peb_Skew | Pebble count asymmetry of distribution. |
| In Channel Habitat - Substrate | Embed_Median | Average amount of embeddedness per stream reach. |
| In Channel Habitat - Substrate | Embed_Het | Heterogeneity (Q84/Q50) of the embeddedness of the study reach. |
| In Channel Habitat - Substrate | Embed_Het2 | Heterogeneity2 (Q10/Q60) of the embeddedness of the study reach. |
| In Channel Habitat - Substrate | Embed_Sorting | Standard deviation of distribution of embeddedness for the study reach. |
| In Channel Habitat - Substrate | Embed_Kurt | Embeddedness peakedness of distribution. |
| In Channel Habitat - Substrate | Embed_Skew | Embeddedness asymmetry of distribution. |
| In Channel Habitat - Hydro | Water_Depth_Median | Median water depth of stream reach. |
| In Channel Habitat - Hydro | Water_Depth_Het | Heterogeneity (Q84/Q50) of the water depth within the study reach. |
| In Channel Habitat - Hydro | Water_Depth_Het2 | Heterogeneity (Q10/Q60) of the water depth within the study reach. |
| In Channel Habitat - Hydro | Water_Depth_Sorting | Standard deviation of the distribution of water depth within the study reach. |
| In Channel Habitat - Hydro | Water_Depth_Kurt | Water depth peakedness of distribution. |
| In Channel Habitat - Hydro | Water_Depth_Skew | Water depth assymetry of distibution. |
| In Channel Habitat - Substrate | FineSed_Depth_Median | Median fine sediment depth of stream reach. |
| In Channel Habitat - Substrate | FineSed_Depth_Het | Heterogeneity (Q84/Q50) of the fine sediment depth within the study reach. |
| In Channel Habitat - Substrate | FineSed_Depth_Het2 | Heterogeneity (Q10/Q60) of the fine sediment depth within the study reach. |
| In Channel Habitat - Substrate | FineSed_Depth_Sorting | Standard deviation of the distribution of fine sediment depth within the study reach. |
| In Channel Habitat - Substrate | FineSed_Depth_Kurt | Fine sediment depth peakedness of distribution. |
| In Channel Habitat - Substrate | FineSed_Depth_Skew | Fine sediment depth assymetry of distibution. |
| In Channel Habitat - Cover | Fish_Cover_Median | Median fish habitat within the study reach. |
| In Channel Habitat - Cover | Fish_Cover_Sorting | Standard deviation of fish habitat within the study reach. |
| In Channel Habitat - Cover | Fish_Cover_Kurt | Fish habitat peakedness of distribution. |
| In Channel Habitat - Hydro | Flow_Type_Median | Median surface flow type of the study reach. |
| In Channel Habitat - Hydro | Flow_Type_Het | Heterogeneity (84/50) of the surface flow type of the study reach. |
| In Channel Habitat - Hydro | Flow_Type_Het2 | Heterogeneity2 (10/60) of the surface flow type of the study reach. |
| In Channel Habitat - Hydro | Flow_Type_Sorting | Standard deviation of distribution of the surface flow type for the study reach. |
| In Channel Habitat - Hydro | Flow_Type_Kurt | Surface flow type peakedness of distribution. |
| In Channel Habitat - Hydro | Flow_Type_Skew | Surface flow type asymmetry of distribution. |
| In Channel Habitat - Substrate | Bed_Veg_Median | Median amount of vegetation cover per stream reach. |
| In Channel Habitat - Substrate | Bed_Veg_Het | Heterogeneity (84/50) of the vegetation cover of the study reach. |
| In Channel Habitat - Substrate | Bed_Veg_Het2 | Heterogeneity2 (10/60) of the vegetation cover of the study reach. |
| In Channel Habitat - Substrate | Bed_Veg_Sorting | Standard deviation of distribution of the vegetation cover for the study reach. |
| In Channel Habitat - Substrate | Bed_Veg_Kurt | Vegetation cover peakedness of distribution. |
| In Channel Habitat - Substrate | Bed_Veg_Skew | Vegetation cover asymmetry of distribution. |

| Parameter | Metric Name | Description |
|---|---|---|
| Bank Condition | Bank_Veg_Type_Median | Median bank cover vegetation type of the stream reach. |
| Bank Condition | Bank_Veg_Type_SD | Standard deviation of the bank cover vegetation type of the stream reach. |
| Bank Condition | Total_Bank_Height_Mean | Mean total bank height for stream reach |
| Bank Condition | Bank_Slope_Mean | Mean bank slope for stream reach |
| Bank Condition | Bankfull_Height_Mean | Mean bankfull height for stream reach. |
| Bank Condition | TBH_BankfullHeight_Ratio | Mean ratio of bankfull height to bank height. |
| Bank Condition | Bank_Erosion_Index | Modified BEHI index to account for bank erosion values within the study reach. |
| Bank Condition - Dendrochronology | Eroding_Percent | Percent of both banks of the 100m that was actively eroding. |
| Bank Condition - Dendrochronology | Dendro_Bank_Erosion_Rate | Stream bank adjusted lateral erosion area rate |
| Longitudinal Profile | Long_Dep_Var | R-squared value from a linear regression on the stream reach's longitudinal profile. |
| Longitudinal Profile | Long_Rough | Longitudinal deviations from calculated slope of reach. |
| Longitudinal Profile | Long_Sinuosity | Ratio of distance of cumulative thalweg distance to straight line distance for study reach. |
| Longitudinal Profile | Stream_Slope | Percent gradient of change in water elevation from the top to the bottom of the study reach. |
| Cross-Section | CSX_Topo_Rough | Cross sectional ratio of topographic distance to straight line distance. |
| Cross-Section | CSX_Dep_CoV | Cross sectional coefficient of variance for depth below bankfull of reach. |
| Cross-Section | CSX_Bankfull_Area | Mean bankfull area of stream reach. |
| Cross-Section | CSX_Total_Area | Total average reach area of the entire channel. |
| Cross-Section | CSX_Area_Ratio | Ratio of reach mean bankfull area to reach mean total channel area. |
| Instream Wood | Instream_Wood_Volume | Total volume of instream large wood in study reach standardized by bankfull channel area |
| Instream Wood | Instream_Wood_Porosity | Mean porosity (i.e. interstitial space) of instream large wood jams. Wood consisting of a single key piece, v wood accumulation, were given porosity of 0. |

# Lists of measurements

## Benthic Macroinvertebrates: computed IBI

| Parameter | Metric Name | Description |
|---|---|---|
| water condition | Weather | weather conditions at the time of sampling |
| Habitat | Temperature (*C) | Stream temperature in degrees Celsius at the time of sampling site, collected for each sample per site. |
| Habitat | pH | measure of how acidic/basic water is, collected for each sample per site. |
| Habitat | Conductivity | ability of water to pass an electrical current, deviation from the expected range allows, collected for each sample per site. |
| Habitat | Specific Conductivity | Indirect measure of the collective concentration of dissolved ions in solution, collected for each sample per site. |
| Habitat | DO (mg/l) | Oxygen dissolves in water to saturation, a value typical of a given temperature. Reported in units of mg/l, or milligrams per liter. collected for each sample per site. |
| Habitat | DO (%) | Percent saturation tells us what part of the holding capacity is actually taken, collected for each sample per site. |
| Habitat | Habitat types | Defined as Undercut banks, Debris Accumulation, Emerging/Submerged algae/vegetation, and Exposed roots. Collected for the whole stream reach per site. |
| Habitat | % Habitat Cover | measured habitat type cover in 1-100% scale, collected for the whole stream reach per site. |
| Taxonomic | Taxa Abundance | Total and Relative abundance of taxa across independent variables (e.g., site, agriculture intensity, BMP/Ag gradient) |
| Taxonomic | Taxa Richness | measure of the number of different kinds of taxa across independent variables (e.g., site, agriculture intensity, BMP/Ag gradient) |
| Taxonomic | Taxa Diversity | mean and variance of the number of taxa across independent variables (e.g., site, agriculture intensity, BMP/Ag gradient) |
| Taxonomic | Taxa Biomass | Taxonomic rankings will be weighted by biomass (total mass of organisms in a given area or volume) using established equations |
| Trait | Functional Trait Diversity | measure of the value and range of functional traits prevailing in an ecosystem, functional trait data of taxa will be taken from the most viable source |
| Trait | Functional Trait Abundance | Total and Relative abundance of functional trait metric across dependent variables (e.g., site, agriculture intensity, BMP/Ag gradient) |
| Trait | Functional Trait Biomass | Functional traits will be weighted by biomass (total mass of organisms in a given area or volume) obtained from taxa biomass within each functional trait metric |

# Lists of measurements

Fish:
Computed IBI

| Parameter | Metric Name | Description |
|---|---|---|
| Reach Info | SiteID | Four letter internal study ID denoting each stream. |
| Reach Info | Reach | "A" denotes the main study reach sampled by all teams. "B" denotes the second reach where only fish were sampled. |
| Reach Info | People | Initials of fish sampling team members present |
| Reach Info | Date | Date of fish sampling |
| Reach Info | Riffle1WidthFt | Wetted width of the first riffle measured |
| Reach Info | Riffle2WidthFt | Wetted width of the second riffle measured |
| Reach Info | Riffle3WidthFt | Wetted width of the third riffle measured |
| Reach Info | Conductivity | Raw (not temperature compensated) water conductivity, units µS/cm |
| Reach Info | WaterTempC | Water temperature, ° C |
| Reach Info | WaterClarityCm | Water clarity measured by lowering a white-painted pyramid sinker into a pool and recording the depth (cm) at which the weight disappears. |
| Reach Info | SeineHauls | Number of seine hauls performed in the reach |
| Reach Info | ReachSamplingNotes | Notes about conditions in the reach |
| FishCatch | Common Name | Accepted common name of fish species collected according to Page et al. (2013) *Common and Scientific Names of Fishes from the United States, Canada, and Mexico*, 7th Edition. American Fisheries Society Special Publication 34. Available: https://doi.org/10.47886/9781934874318 |
| FishCatch | <30 | Number of fish <30 mm long (total length) of the given Common Name collected in the given pass |
| FishCatch | 30-60 | Number of fish 30-60 mm long (total length) |
| FishCatch | 60-90 | Number of fish 60-90 mm long (total length) |
| FishCatch | 90-120 | Number of fish 90-120 mm long (total length) |
| FishCatch | 120-150 | Number of fish 120-150 mm long (total length) |
| FishCatch | 150-200 | Number of fish 150-200 mm long (total length) |
| FishCatch | 200-250 | Number of fish 200-250 mm long (total length) |
| FishCatch | 250-300 | Number of fish 250-300 mm long (total length) |
| FishCatch | 300-400 | Number of fish 300-400 mm long (total length) |
| FishCatch | 400-500 | Number of fish 400-500 mm long (total length) |
| FishCatch | 500+ | Number of fish 500+ mm long (total length) |
| FishCatch | Total Catch | Total number of fish collected |
| FishCatch | Mort | Number of fish that died during the given pass |
| FishCatch | Voucher | Number of fish retained as voucher specimens at Virginia Tech |
| FishCatch | Deformity | Number of fish having an externally visible deformity |
| FishCatch | Erosion | Number of fish having eroded fins |
| FishCatch | Lesion | Number of fish having an externally visible lesion |
| FishCatch | Tumor | Number of fish having an externally visible tumor |
| FishCatch | Total Anom | Total number of fish with anomalies |

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# Lists of measurements

Riparian:

*Natural Buffer Lateral Width*

*Natural Buffer Longitudinal Continuity*

*Lateral Land Surface Slope*

*Land Surface Topographic Complexity*

*Lateral Rills & Channels*

*Soil Wetness*

*Soil Disturbance*

*Living Tree Basal Area*

*Natural Vegetation Disturbance*

*Coarse Woody Debris*

*Riparian Livestock Access*

*Channel Livestock Access*

*Forestry Activity*

*Active Cropping*

*Surface Hydrologic Connectivity*

*Sediment Deposition*

*Scientist's Perception of Quality*

*Scientist's Experiential Synthesis*

*Other notes*

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