The Application of a Multivariate Statistical Analysis to Identify Potential Ongoing Contaminant Sources to an Urban River

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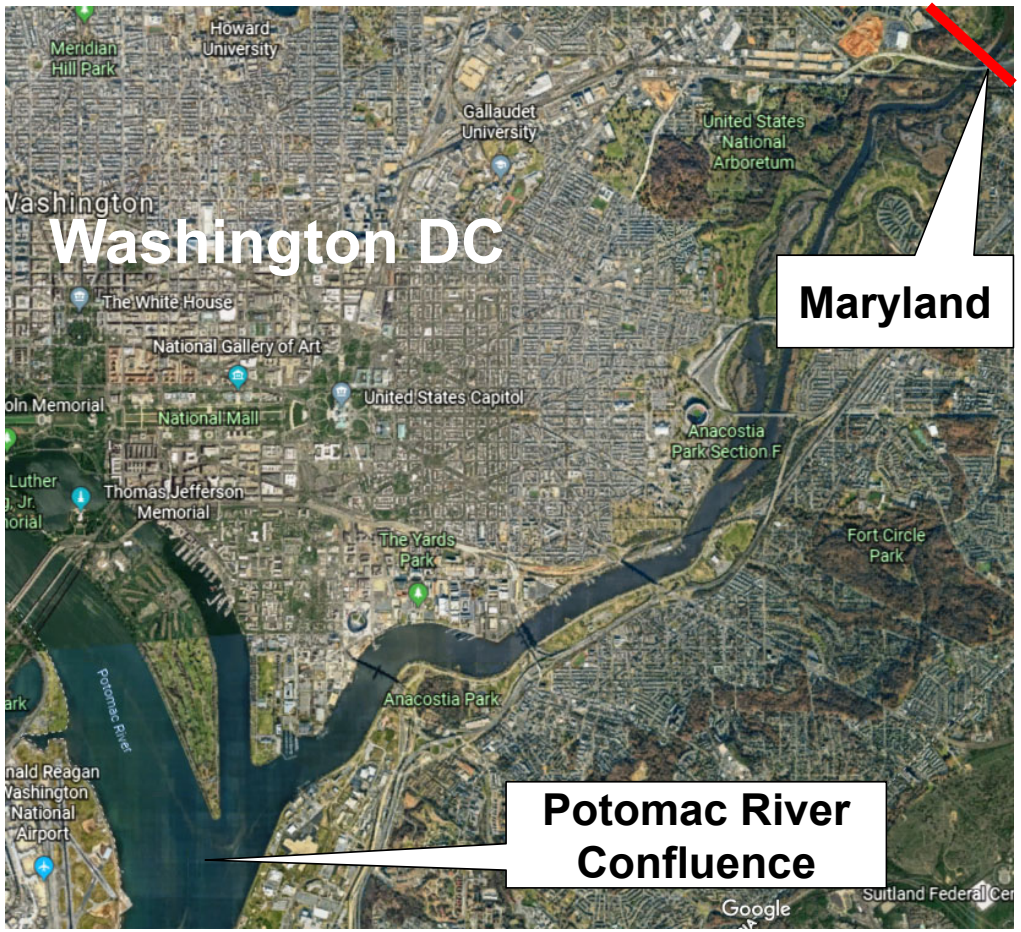
Site Description

- Anacostia River
  - District of Columbia
  - Historically industrialized urban watershed
- Approximately 9 miles under tidal influence
  - Kingman Lake
  - Washington Channel
- Multiple potential sources
  - 119 municipal outfalls
  - 14 named tributaries
  - 13 Potential environmental cleanup sites (PECS)



Study Objectives and Rationale

Objectives:

- ❖Identify likely ongoing currently active sources of contaminants to the tidal Anacostia River
- ❖Set groundwork for detailed forensic evaluation of identified potential sources
- ❖Provide information focusing FS evaluations on essential contaminants and spatial locations
- ❖Inform remedial decision making

Rationale:

- ❖Targeting currently active sources by focusing on surface sediment
- ❖Tributaries largest sediment source,
  - ➢ Absent local ongoing sources river and tributary signatures should be similar
  - ➢ Local anomalies are indicative of sources
- ❖Evaluating a suite of chemicals measured in each of three media
  - ➢ River surface sediment
  - ➢ Tributary sediment
  - ➢ Manhole sediment

Multivariate Data and Sediment Pre-processing

- Total of 264 chemical compounds
  - 209 PCB Congeners
  - 34 Parent and Alkylated PAHs
  - 21 Metals
- Samples from 548 total locations
  - Surface Sediment N=472
  - Manholes N=67
  - Tributaries N=9

- PCB Congeners characteristic of Aroclors 1242, 1248, 1254, 1260 and 1268 retained
- Chemicals with more than 5% missing values removed
- Rows with missing values removed
- 203 sediment samples and 73 chemicals
  - 15 PCB congeners
  - 23 Metals
  - 20 Parent and 15 alkylated PAHs
- Transformed / centered and scaled

Multivariate Analysis Approach

Dimension Reduction

Chemistry Data

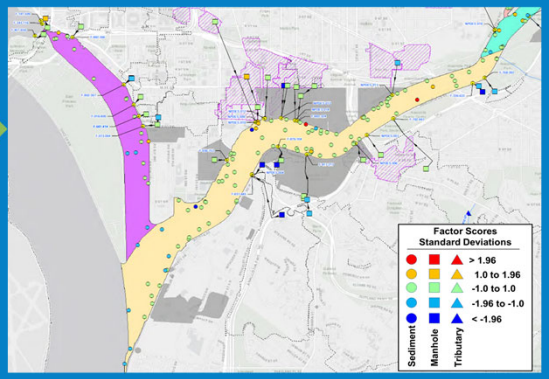
(Surface Sediment)

264 Chemical Compounds

Factor Analysis Varimax Rotation

- **Develop loadings and scores from sediment data**
- **Independently score tributary and manhole data**

Map scores and identify anomalies

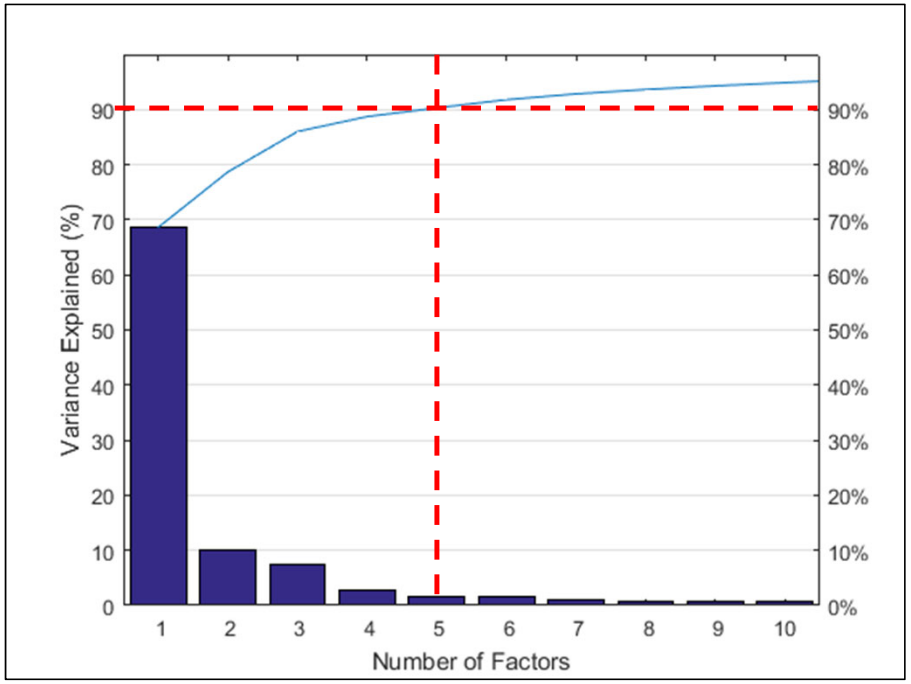


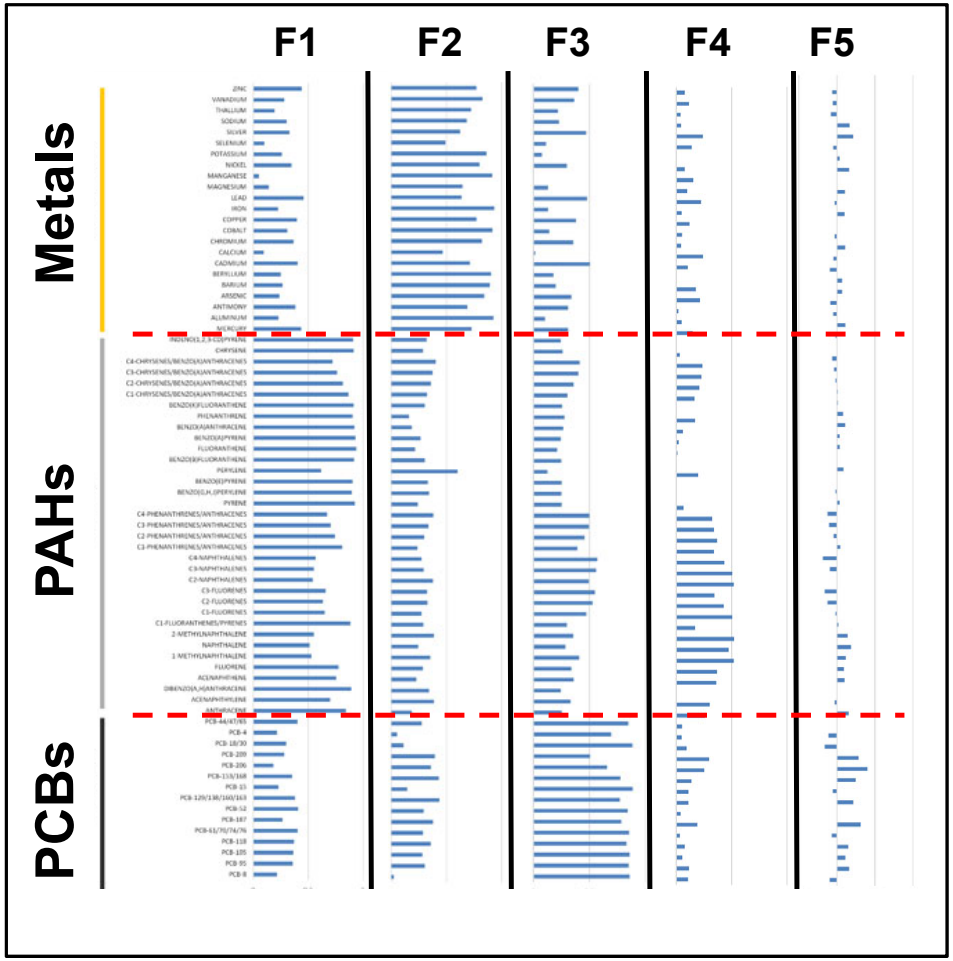
Note:

1) Factor and principal components analyses are terms commonly applied to the same and/or differing statistical algorithms.
2) Generally PCA is the first step in a Factor Analysis where principal axes are rotated to develop interpretable independent components.
3) Other differentiating steps include how the data matrix is scaled and if the data matrix is transposed prior to analysis.

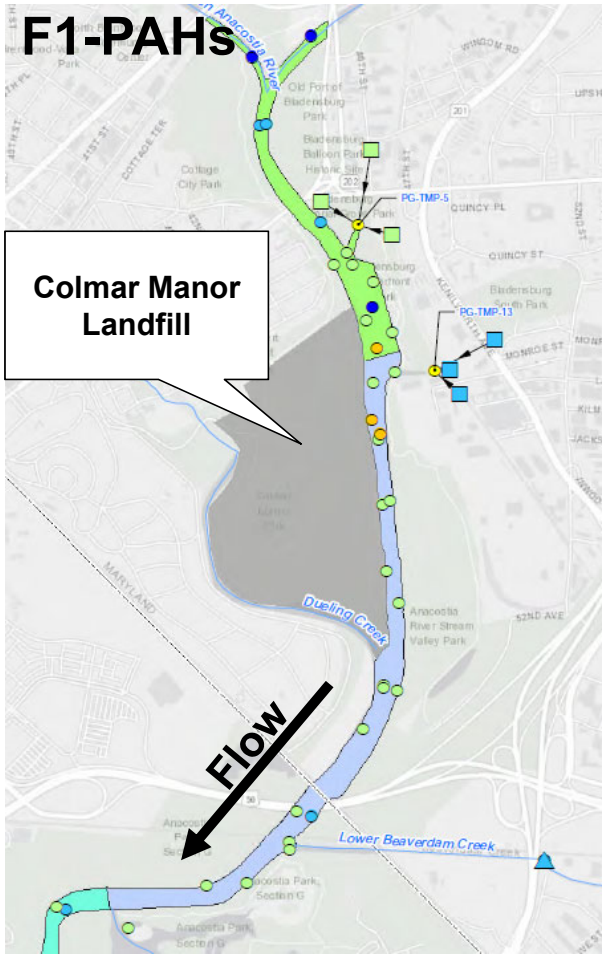
Factor Analysis Results

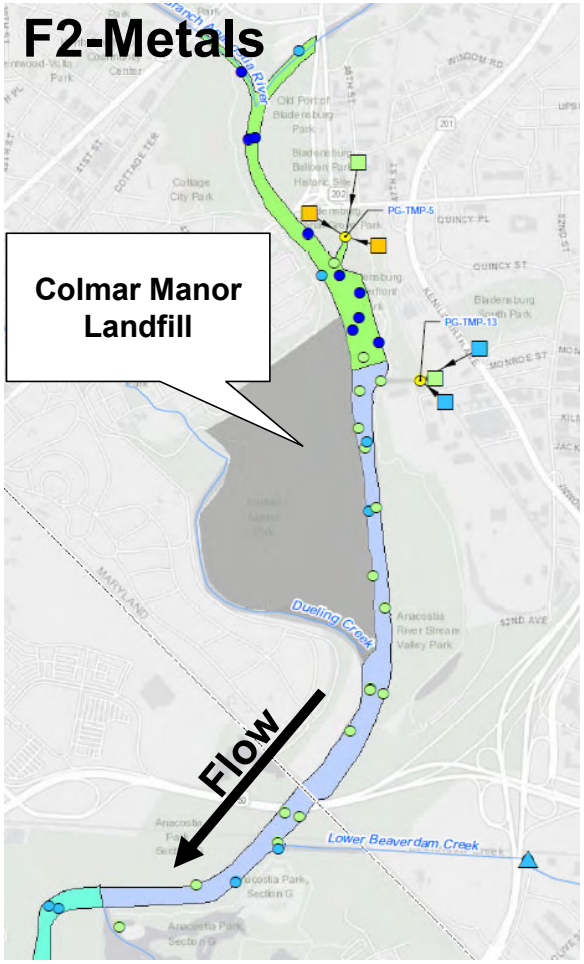
Five Factors Explain 90% of Variance

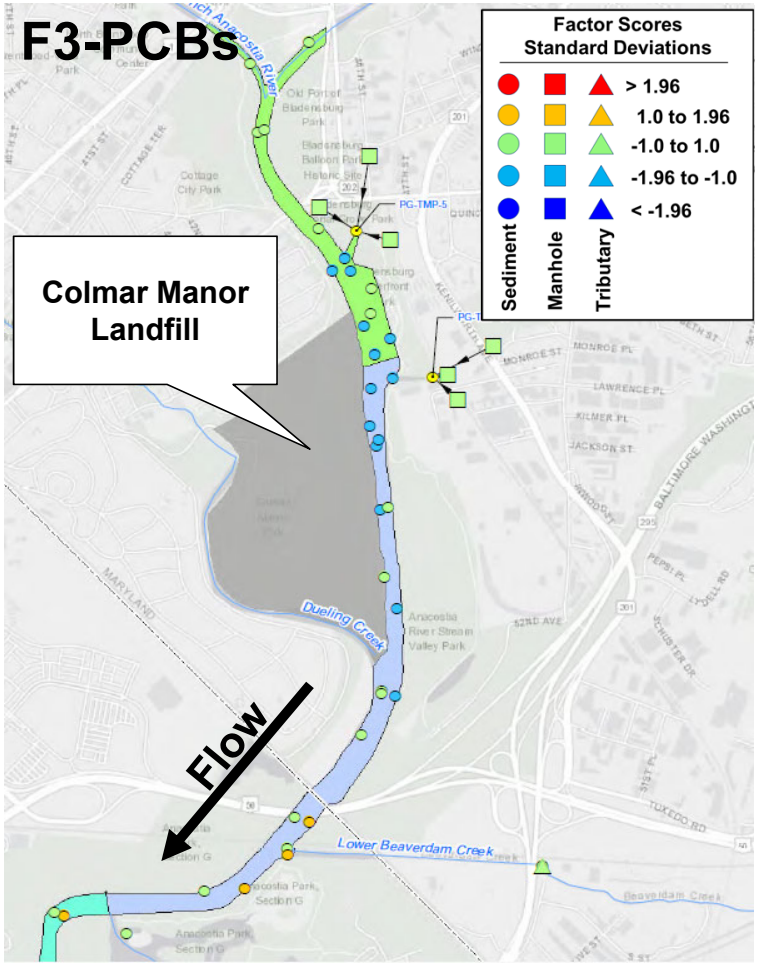




Factor Score Mapping in Sediment –Tributaries - Manholes







Broad Spatial Patterns (Factor 1 Parent and Alkylated PAHs)

❖Tributaries

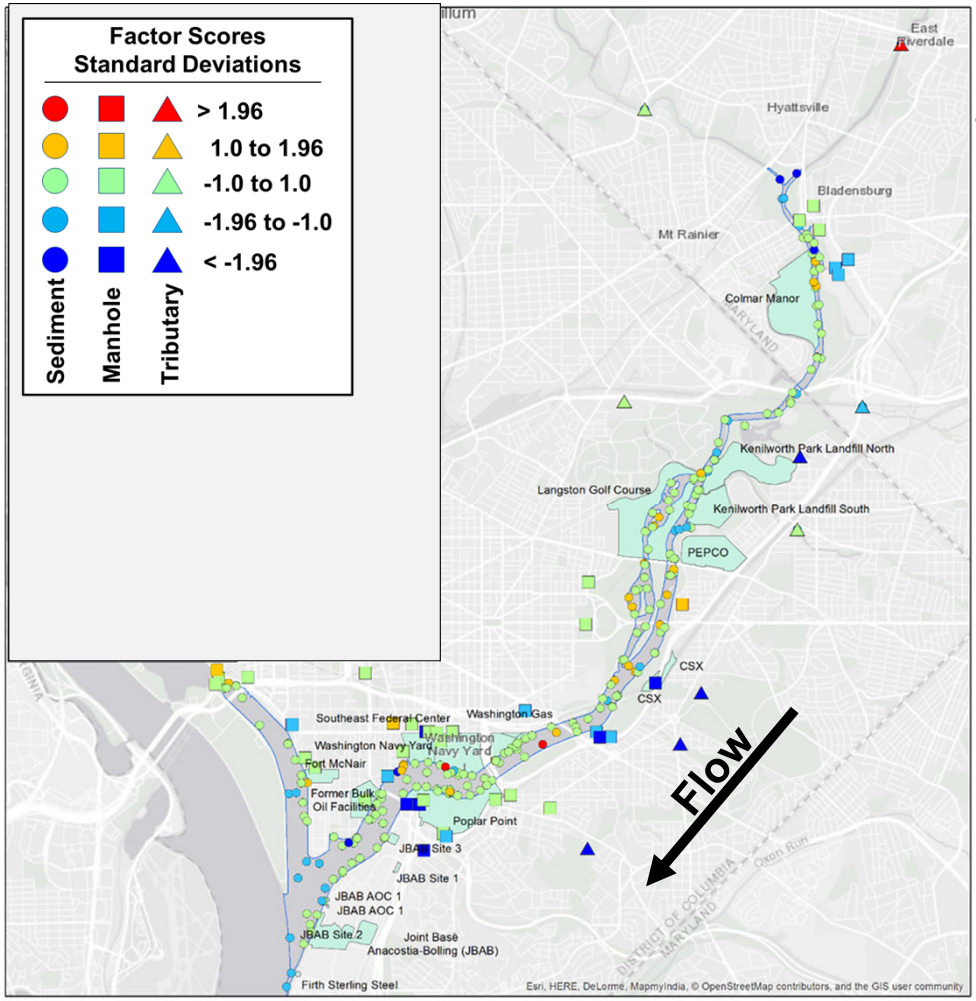
- Similar to or below average levels
- One exception

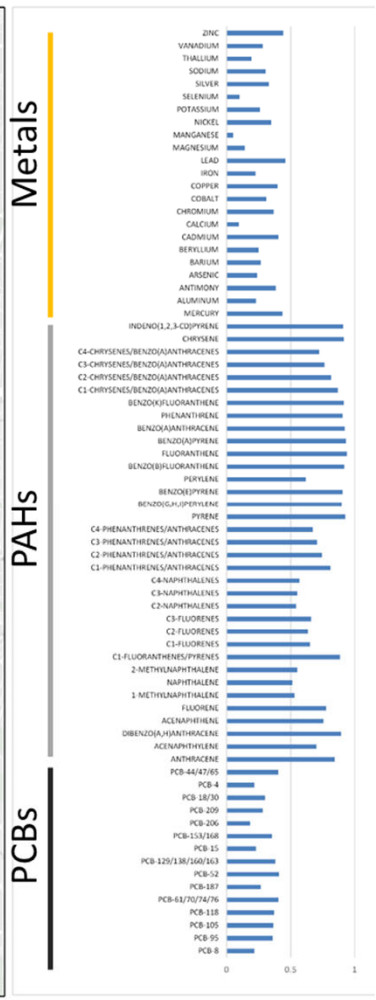
❖Manholes

- Some cases exceeding one standard deviation above the mean
- Predominantly more industrialized downstream areas
- No samples more than 2 standard deviations greater than the mean

❖Surface Sediment

- Highest levels downstream of landfills to the Washington Navy Yard
- Localized groups of elevated samples





Broad Spatial Patterns (Factor 2 Metals)

❖Tributaries

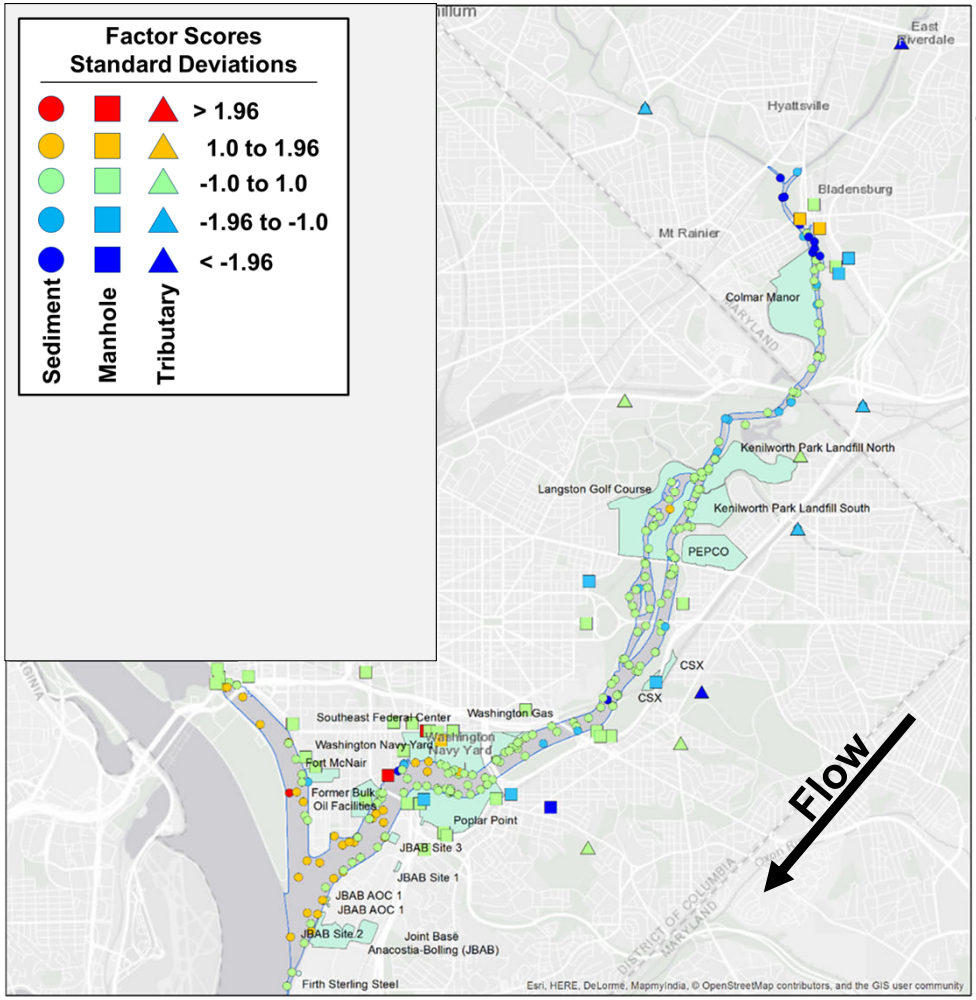
- Similar to or below average levels
- One exception

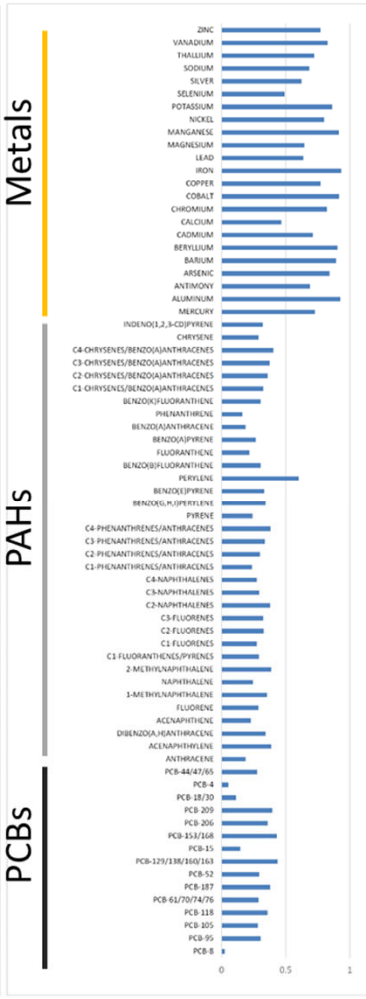
❖Manholes

- Some cases exceeding one standard deviation above the mean
- Predominantly downstream
- No samples more than 2 standard deviations greater than the mean

❖Surface Sediment

- Increasing gradient from upstream to downstream
- Localized groups of elevated samples
- Highest and most spatially contiguous high values near confluence





Broad Spatial Patterns (Factor 3 PCBs)

❖Tributaries

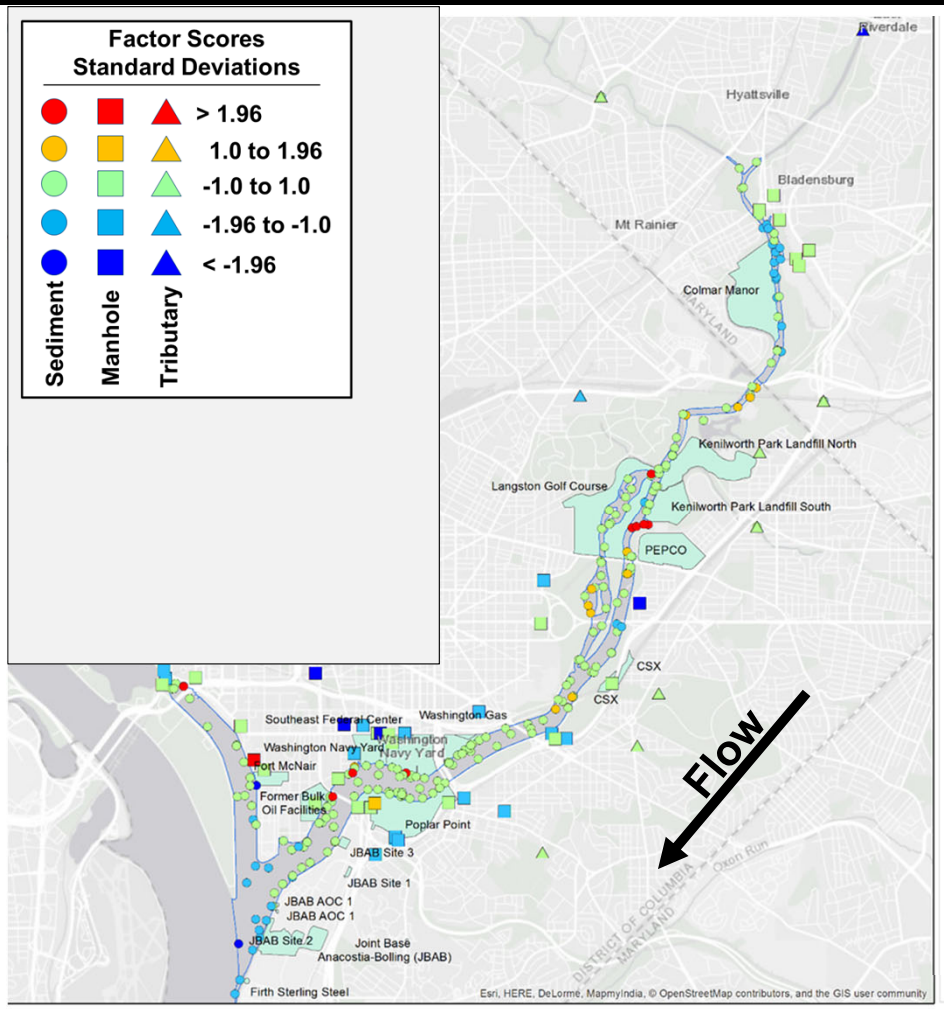
- Similar to or below average levels
- One exception

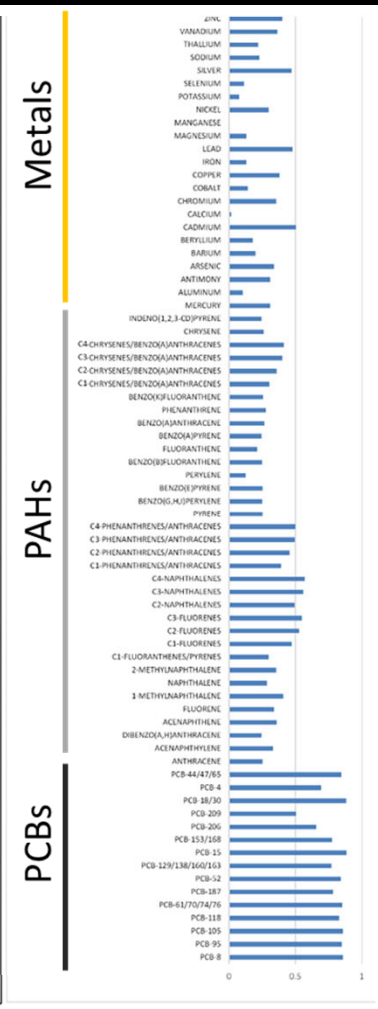
❖Manholes

- Some cases exceeding one standard deviation above the mean
- Predominantly downstream
- No samples more than 2 standard deviations greater than the mean

❖Surface Sediment

- Increasing gradient from upstream to downstream
- Localized groups of elevated samples





Broad Spatial Patterns (Factor 4 Alkylated PAHs)

❖Tributaries

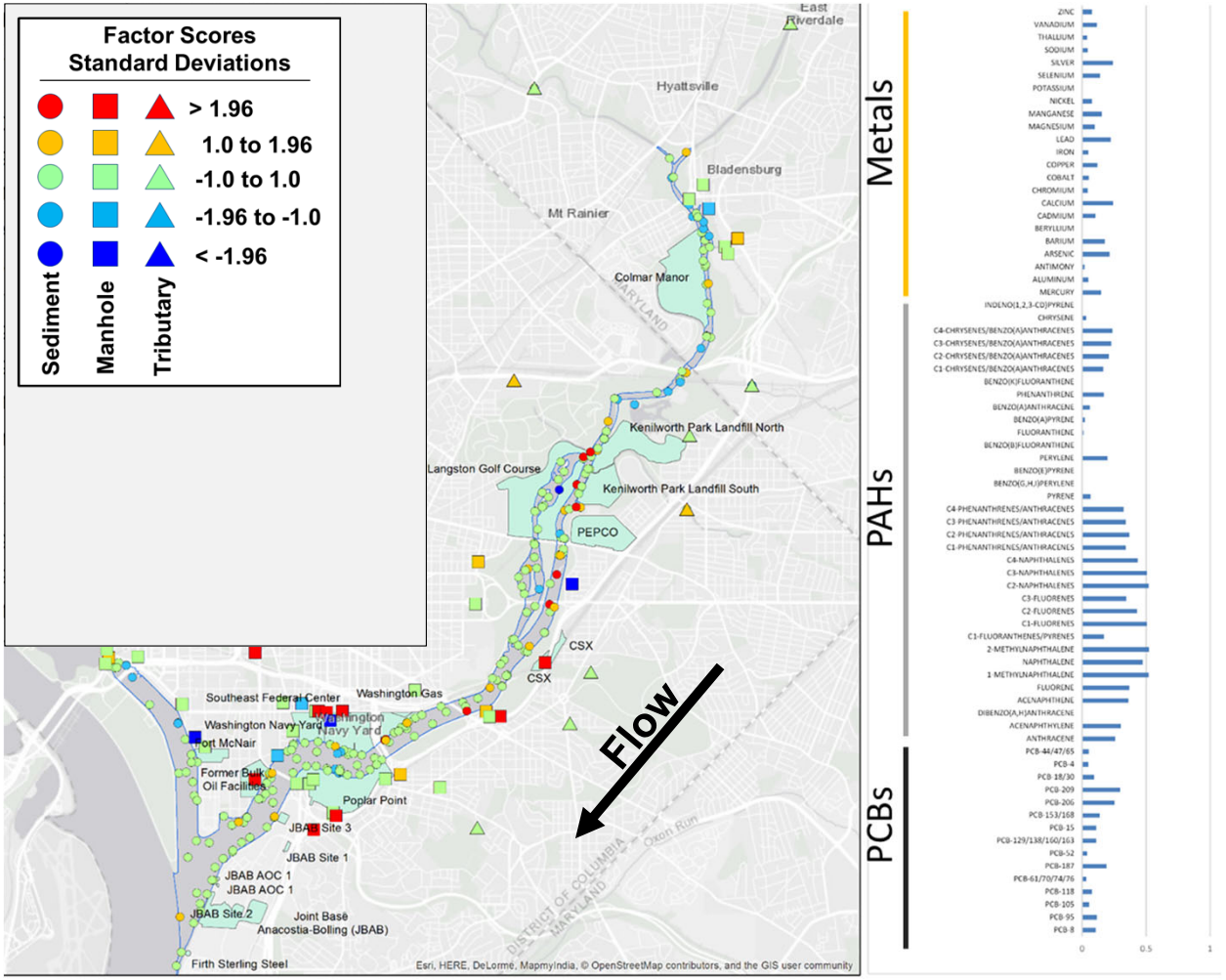
- Two tributary samples above average

❖Manholes

- Several manhole samples >1.96 x SD above average
- Downstream of landfills to confluence

❖Surface Sediment

- Most extreme values near landfills
- Localized groups of moderately elevated samples closer to the confluence



Broad Spatial Patterns (Factor 5 PCB 206 / 209)

❖Tributaries

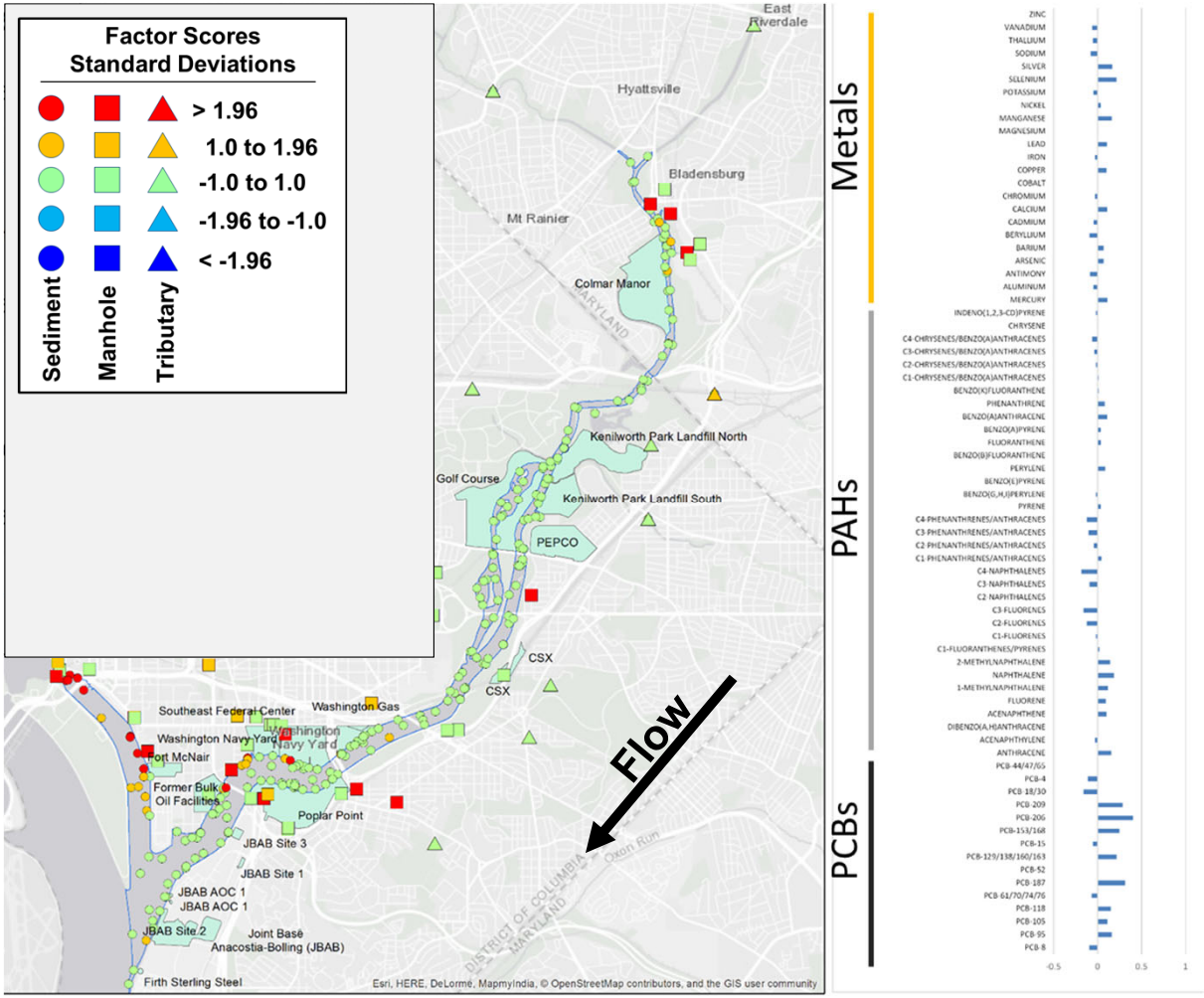
- Just one sample above average

❖Manholes

- Several manhole samples >1.96 x SD above average
- Concentrated areas proximal to industrial areas
- Samples near Bladensburg

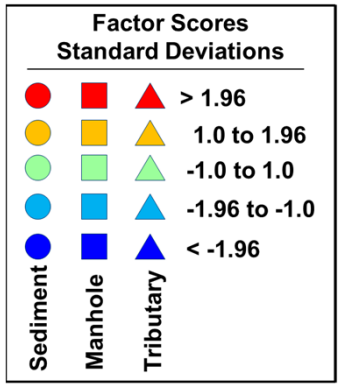
❖Surface Sediment

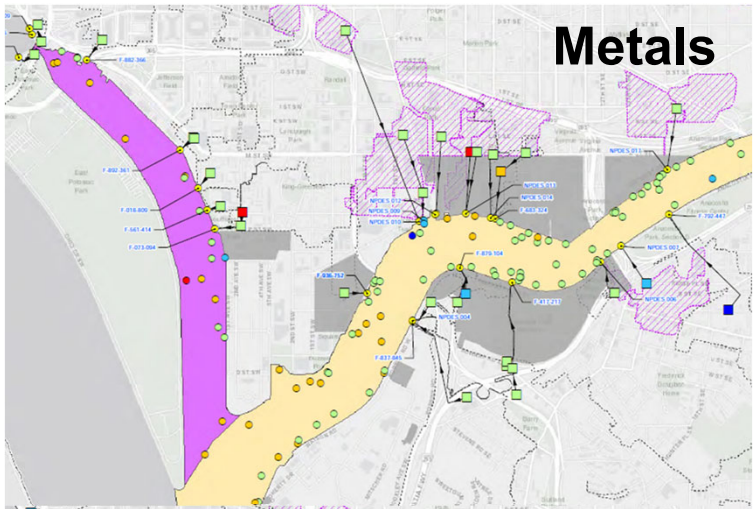
- Localized groups of elevated samples proximal to manhole samples
- Patterns differ from other factors with more tight linkage between sediment and manholes

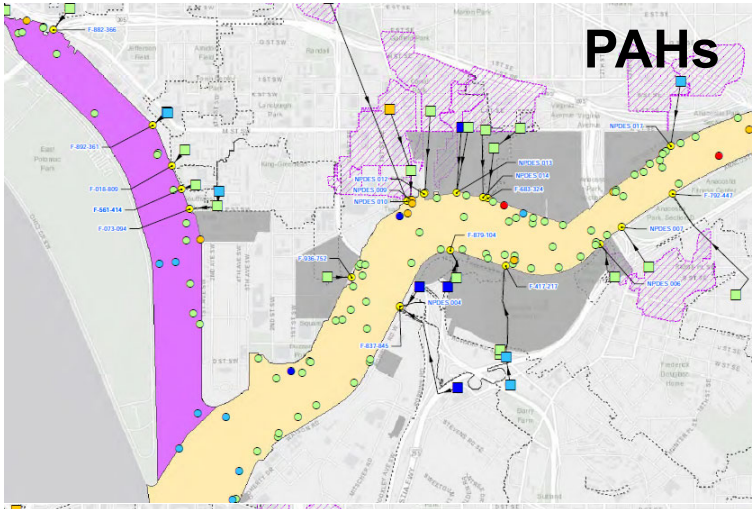


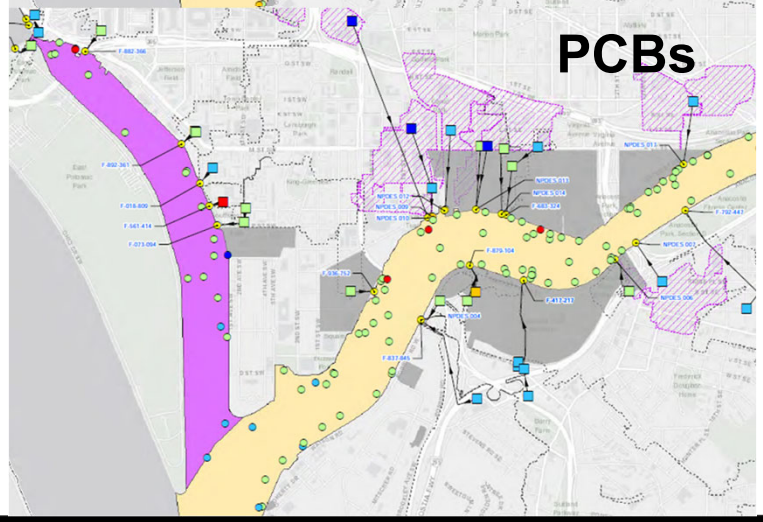
Side by Side Comparisons

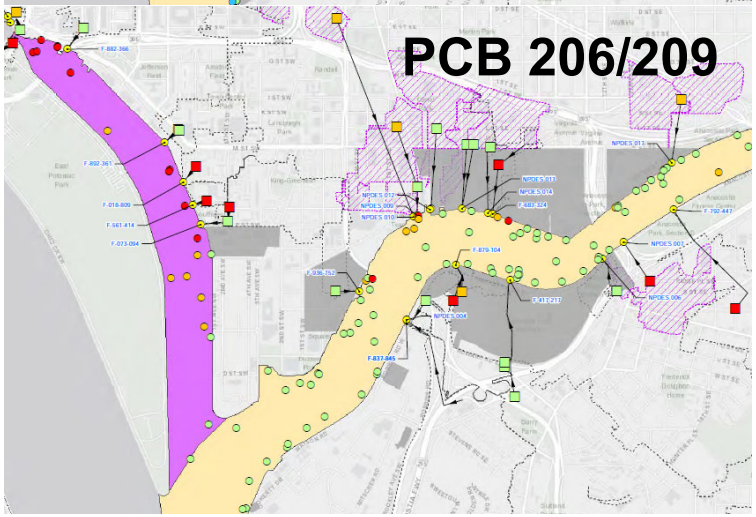
- Metals laterally extensive in the downstream area
- PAHs largely evenly distributed with few extremes
- PCBs exhibit 3 localized sediment extremes
- PCB 206/209 several manhole sediment connections











Summary

- Spatial patterns were found using an unguided descriptive approach
- Identified patterns were consistent with the industrial history of the tidal river
- The FS will include further inferential/causative evaluations of relationships
- Chemical composition in surface sediment and tributaries was similar (i.e., within 1xSD of central tendency)
- General upstream to downstream gradients were identified
- Locally elevated values of Metals, PAHs, Alkylated PAHs and PCBs were identified for subsequent investigation
- Some apparent sources were proximal to manhole samples or industrial properties which may be indicative of current and ongoing sources
- Further investigation to firm up apparent relationships will be ongoing