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Modeling Contaminant Transport Utilizing a Combined Hydrodynamic Sediment Transport and Contaminant Box Model

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Agenda

- Role of Contaminant Transport Modeling in Recontamination Assessments
- Overview of Combined Contaminant Modeling Approach
- Approaches for contaminant transport model validation
- Potential for Model Refinements
- Conclusions

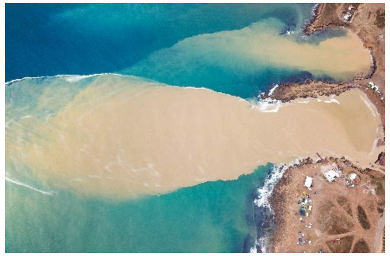
Recontamination Assessments Can Protect Your Investment in Sediment Remediation

- Sediment remediation in complex waterway superfund projects can be expensive
  - Portland Harbor estimate: $1.13 billion (EPA 2019)
  - LDW estimate: $327 million (EPA 2014)
- In the Pacific Northwest, EPA has begun requiring source control sufficiency assessments as part of the design process to avoid re-contamination of these expensive remediations
- These analysis are complicated by the multiple potential contaminant sources

Stormwater discharges

Spills from overwater vessels or structures

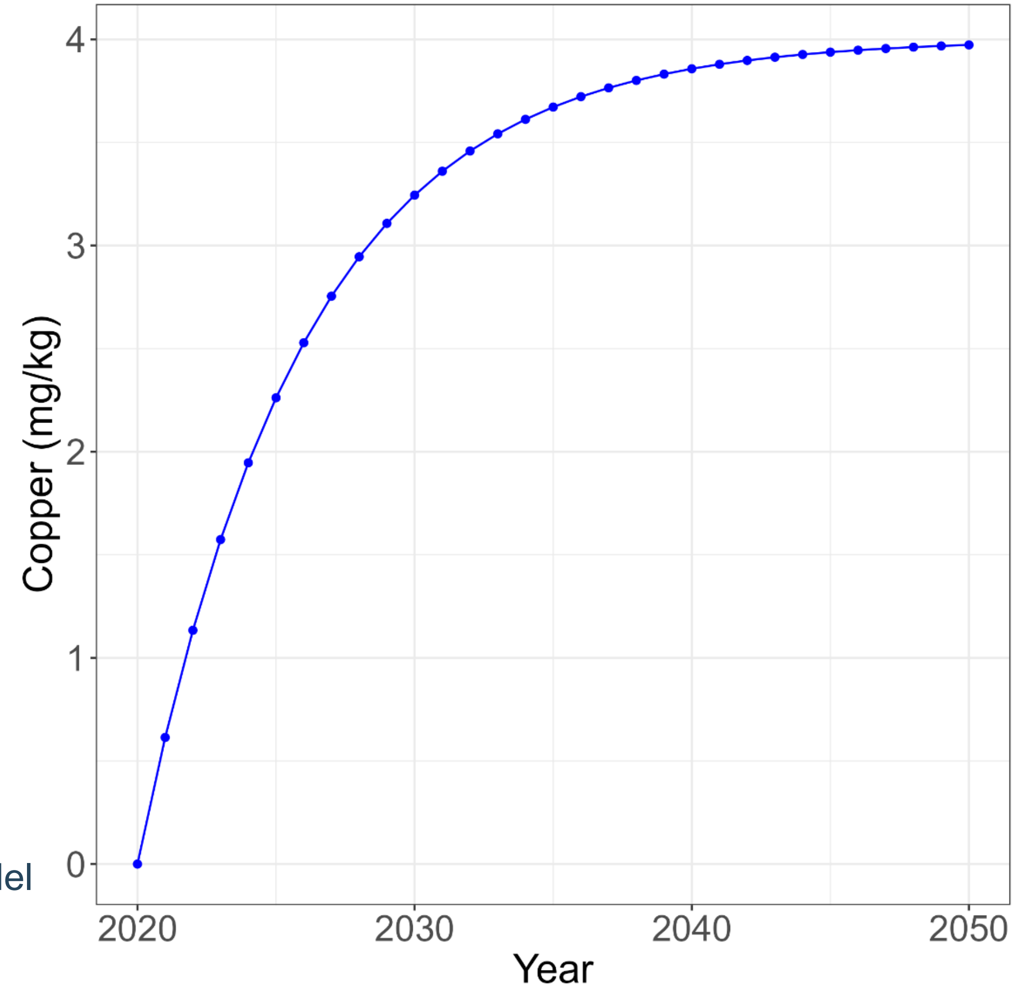
Sediment transport



Fires on overwater structures or vessels

Modeling Contaminant Transport in an Assessment Can Predict Re-Contamination

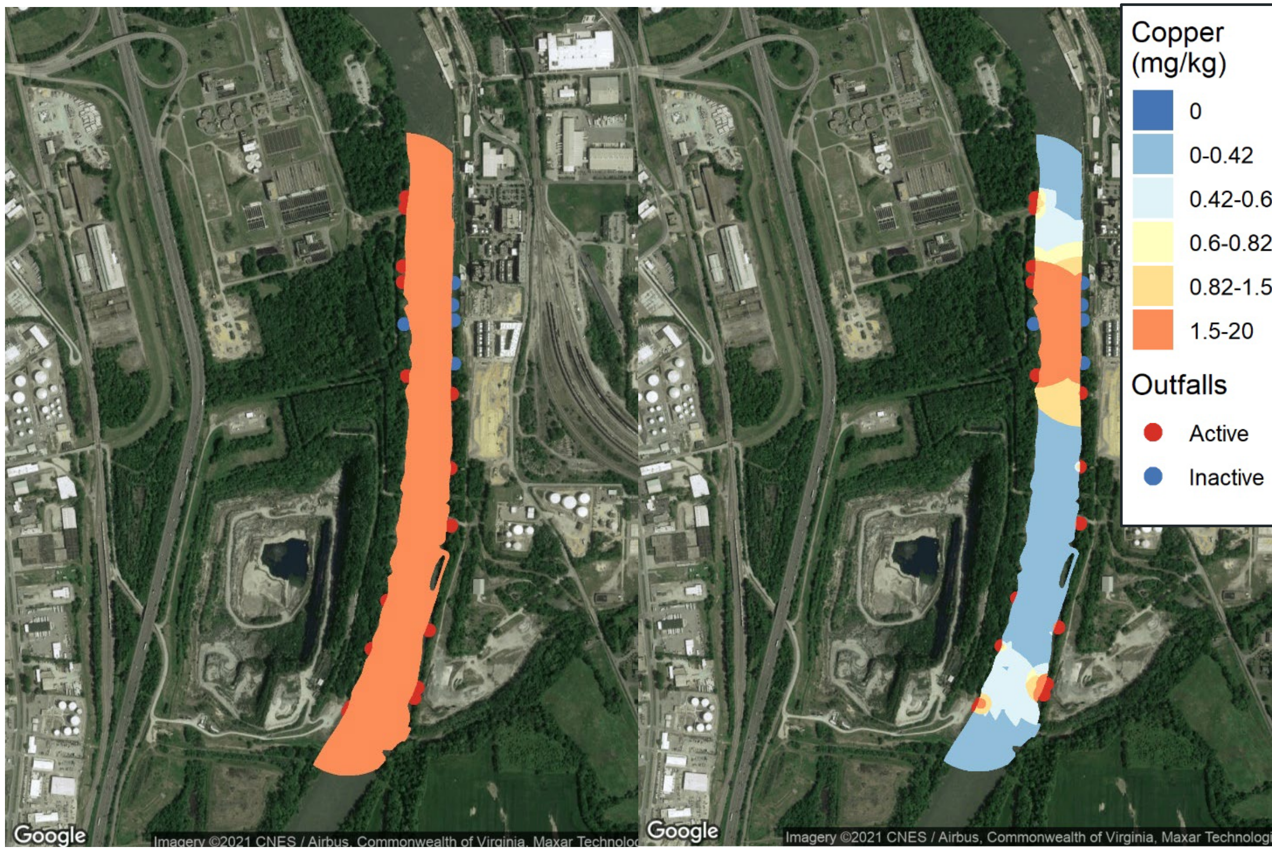
- Modeling approaches evaluate entire river system accounting for complex interactions not accounted for in other approaches (such as criteria comparison for stormwater samples)
- There are many ways to model contaminants
  - Box models (such as SEDCAM)
  - Hydrodynamic particle tracking models
  - Combined hydrodynamic and box models



Lucinda Jacobs, Robert Barrick, and Thomas Ginn, “Application of a Mathematical Model (SEDCAM) to Evaluate the Effects of Source Control on Sediment Contamination in Commencement Bay”, 1998

Models Have Different Pros and Cons

- Box Models
  - Pros: easy to understand, quick, inexpensive
  - Cons: coarse resolution, limited accuracy
- Combined hydrodynamic and box models
  - Pros: finer resolution, accurate, quick
  - Cons: medium costs, detailed inputs
- Particle tracking models
- Pros: fine resolution, accurate
- Cons: long run times, costly, large input requirements
- Model selection should be project specific

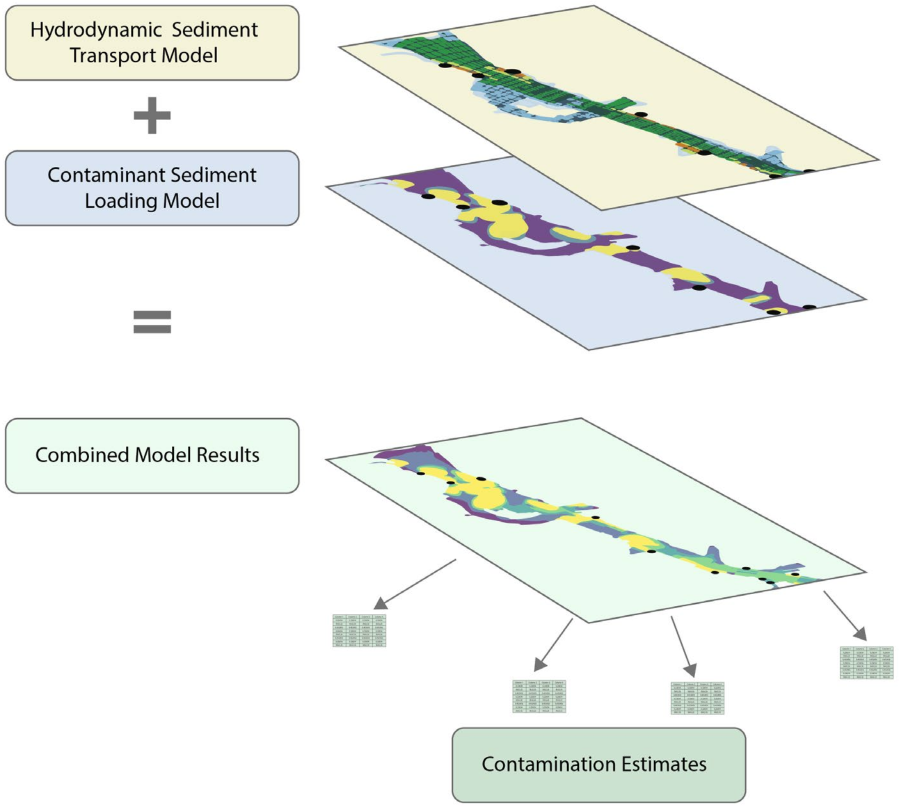


What Does a Combined Model Look like?

- Combined models rely on hydrodynamic sediment transport models results as input to box model
- Accuracy and specificity depend on detail of hydrodynamic model and contaminant box model

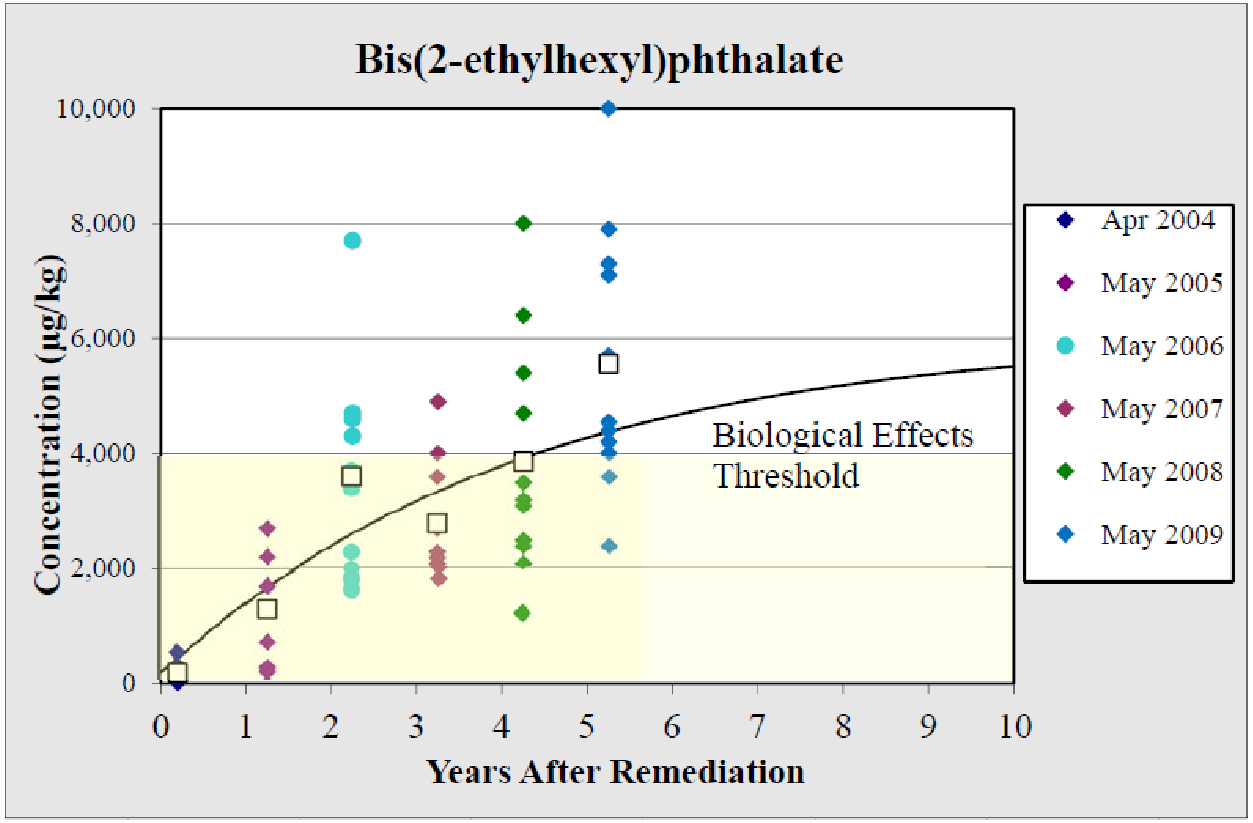
$$C_t = \frac{M}{(M+kS)} \times C_I \times \left[1 - e^{\frac{-(kS+M)t}{S}}\right] + C_O \times e^{\frac{-(kS+M)t}{S}}$$

- Model grid is based on hydrodynamic model grid and other required box model inputs



Combined Models have Been Used to Identify Potential Recontamination Issues

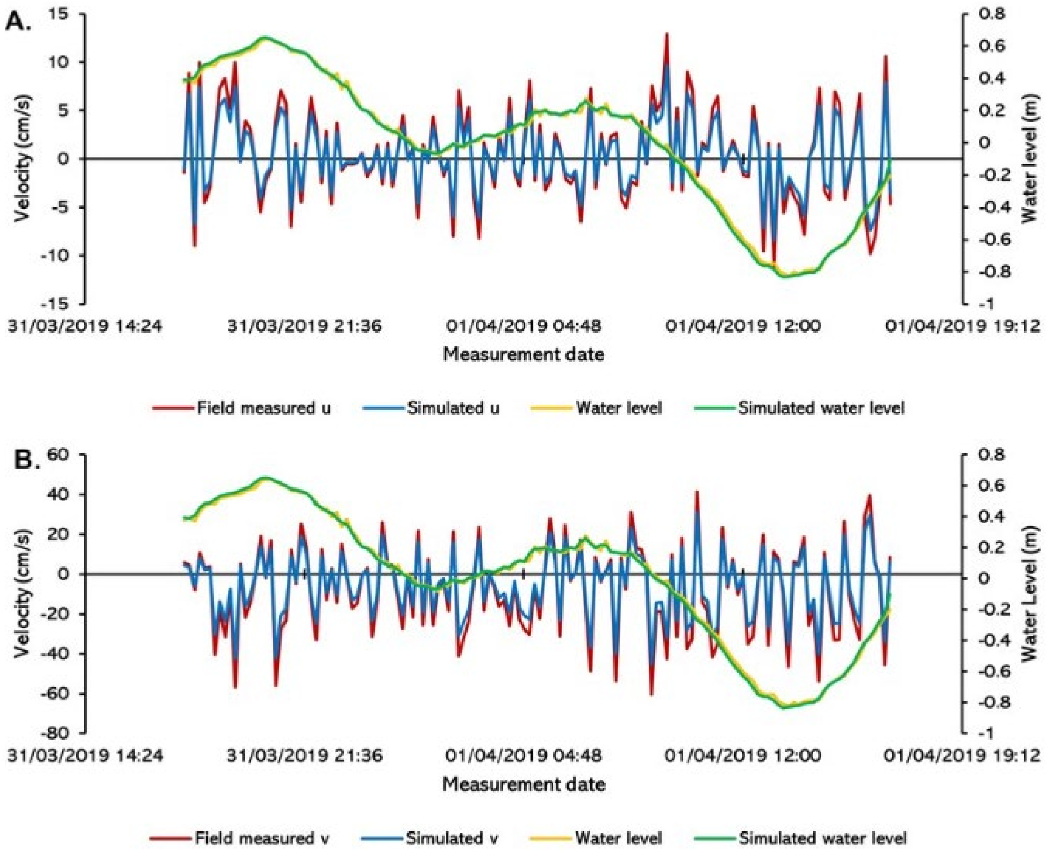
- Thea Foss Waterway: WASP model of SW and sediment for sections of waterway
  - Identified recontamination from BHEP
- LDW: Bed Conceptual Model (BCM) combined lateral and upstream sediment contributions from hydrodynamic model with sediment COC concentrations
- Swan Island Basin: Combined hydrodynamic modeling, stormwater discharge modeling, and SEDCAM



Monitoring and Modeling the Effects of Stormwater Source Controls on Sediment Quality in Tacoma, Washington
Dana B. de Leon, P.E., Mary L. Henley, P.E., and Todd M. Thornburg, Ph.D.

Models Validation Presents Unique Challenges

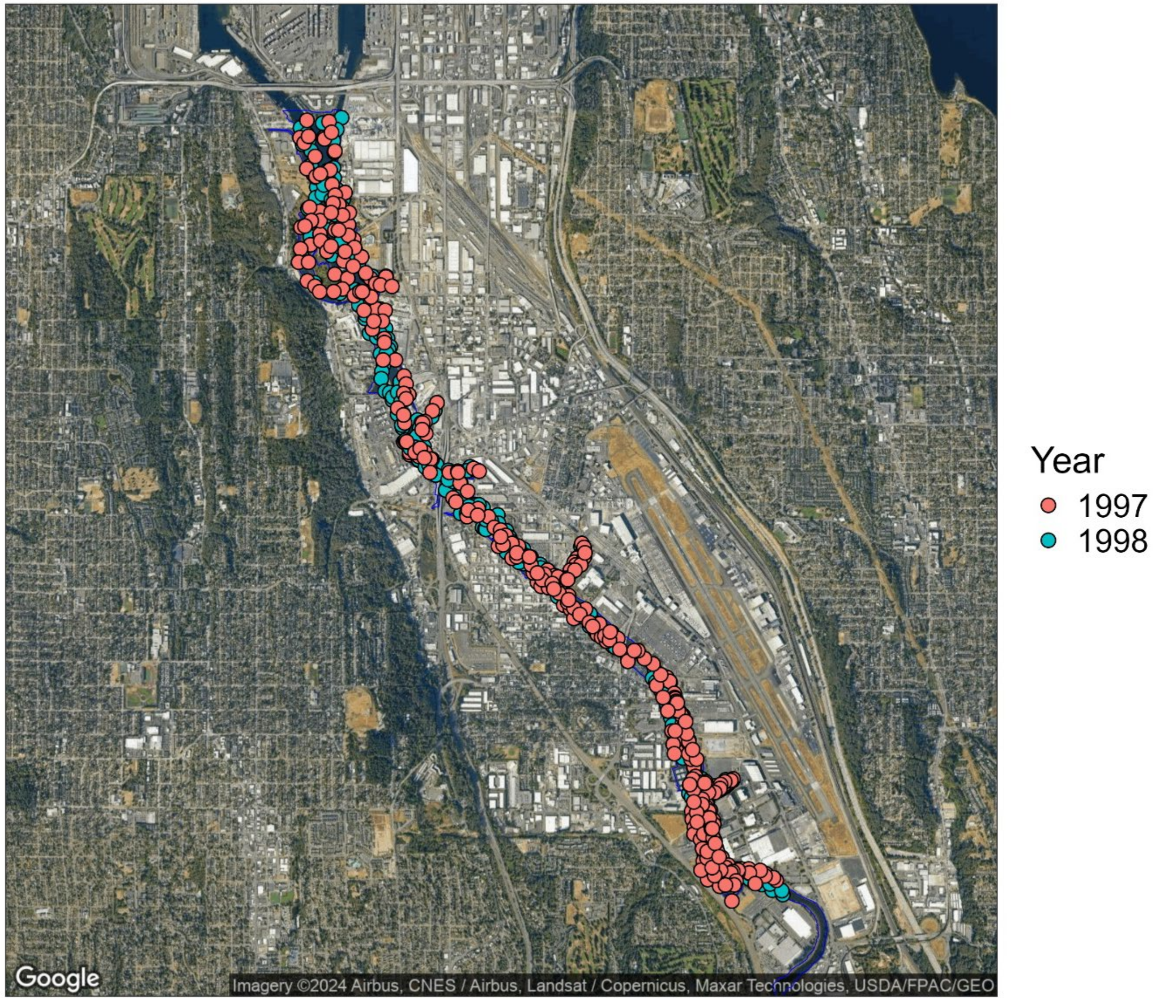
- Hydrodynamic models have large continuous datasets for calibration and validation
- Contaminant transport models
  - don’t have continuous or large validation datasets
  - start with future conditions
  - Include large number of contaminant sources to model
- Validation challenges can be overcome to some extent by identifying appropriate metrics



Trapped Sediment in Seagrass Ecosystem: Bintan Island. Dewi Surinati et. al.

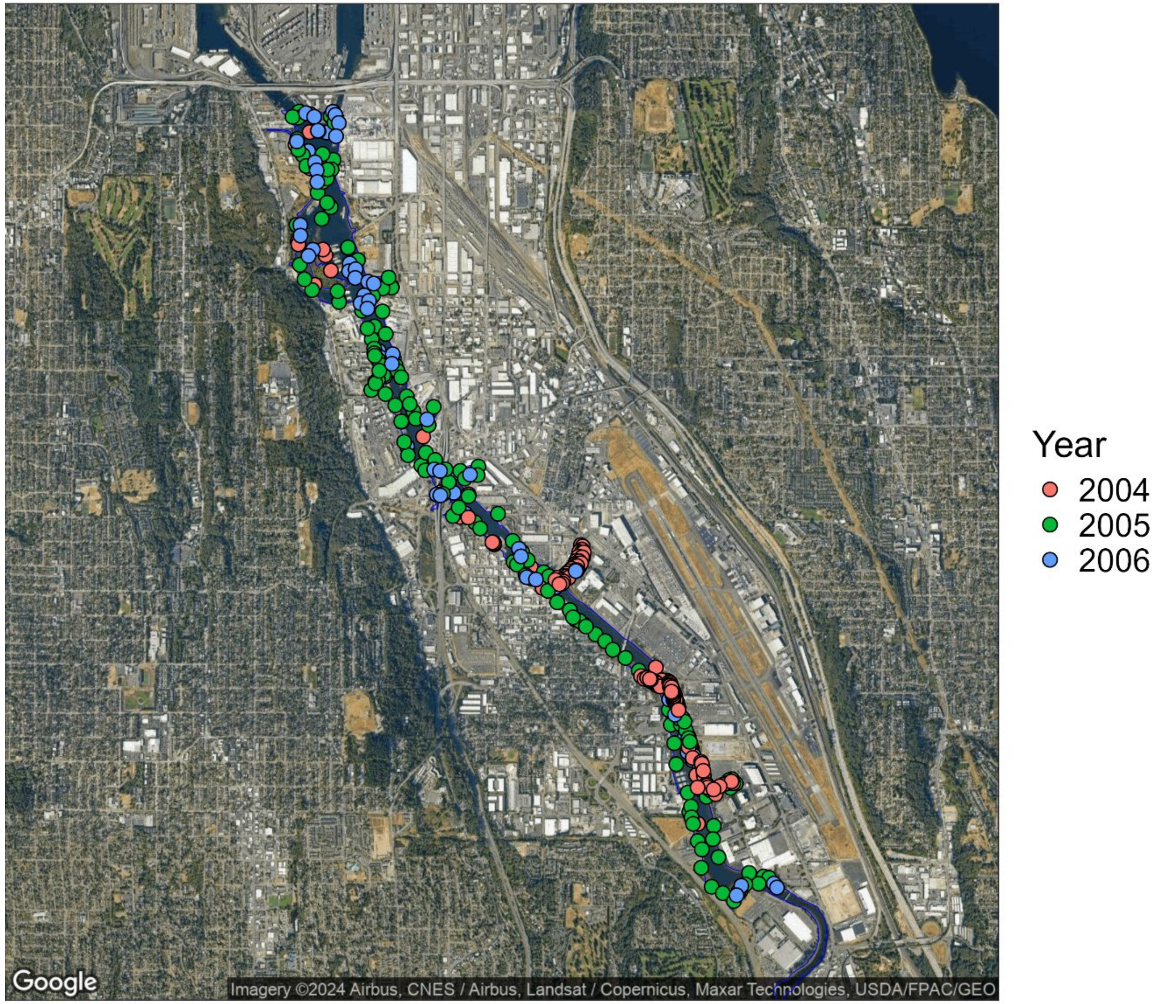
Contaminant Transport Model of LDW

- **Surface (0-10 cm) contamination**: natural neighbors interpolations of FS samples collected in 1997 and 1998 and analyzed for all COCs
- **Outfall COC mass loads**: FS and LDW AOC3 database inline solids
- **Upstream COC mass loads**: LDW AOC3 database upstream suspended solids sampling
- **Solids Loading**: upstream and lateral fractions at year 10 from the HST scenario "sedtran_0712_02_1960_1969_20080101"



Validation Requires Careful Selection of Metrics and Dataset

- 2004-2006 FS surface sampling data used for validation
  - Good spatial coverage
  - Narrow sample time period
  - Relatively recent model results
- Metrics for Evaluation
  - Point comparison
  - Site-wide changes
  - RM SWACs
  - Screening Level exceedance/non-exceedance

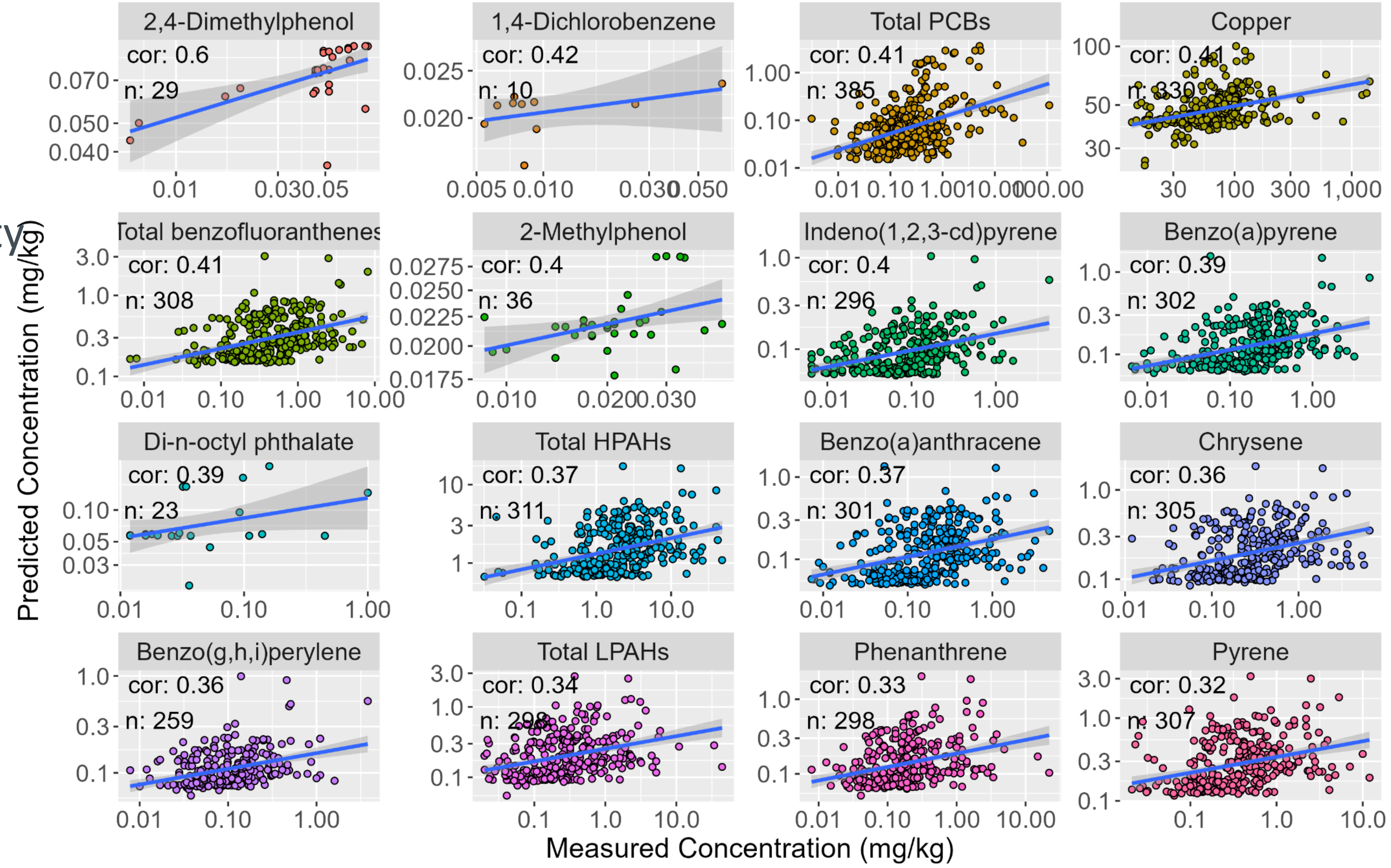


Validation Must Avoid Sampling Biases

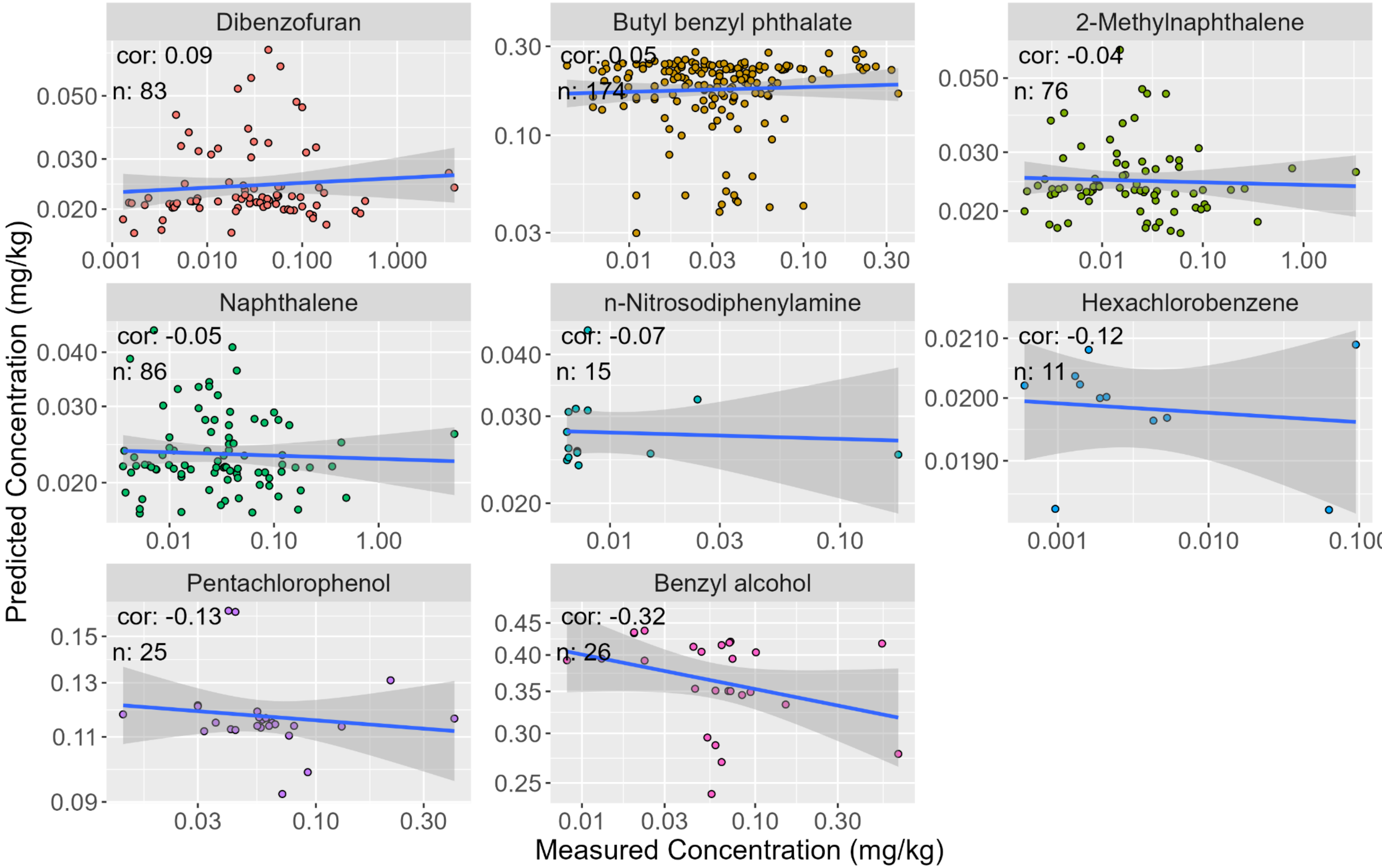
- Validation Data consisted primarily (55%) of remedial investigation samples
  - Likely to capture wide-range of areas including areas away from sources
- Validation Data also captured early action areas (EAA)
  - Careful consideration for existing/historic source bias

Sampling Task	2004	2005	2006
8801 E Marginal (formerly KenworthPACCAR)			28
BoyerTowing	4		
DuwDiagJan2005		5	
Ecology SPI			31
JorgensenAugust2004	47		
LDWRI-Benthic	34		
LDWRI-SurfaceSedimentRound1		77	
LDWRI-SurfaceSedimentRound2		78	
LDWRI-SurfaceSedimentRound3			45
RhônePoulenc2004	23		
Slip 4 EAA 2008			5
Slip4-EarlyAction	34		
T117BoundaryDefinition	19		
Total	161	160	109

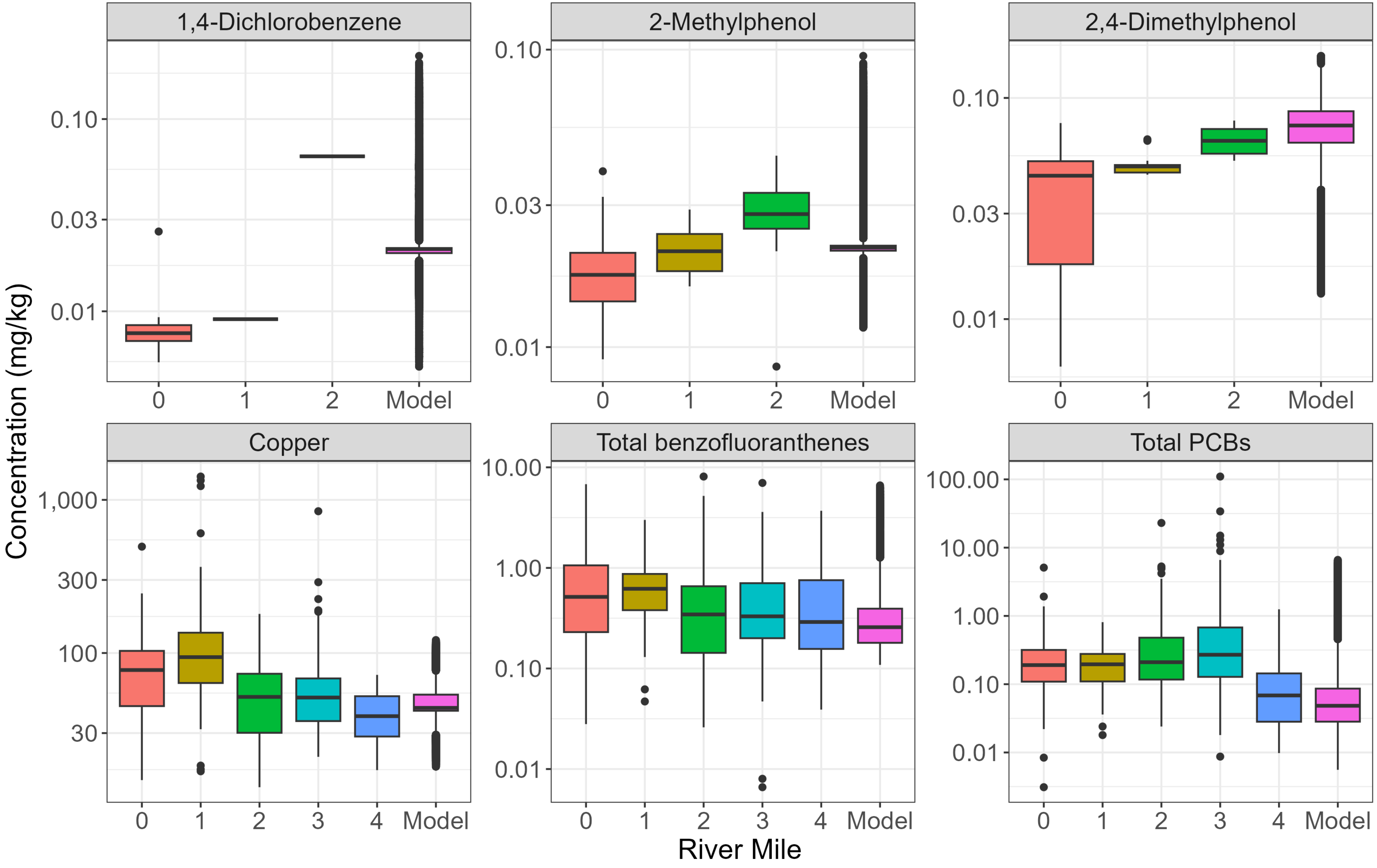
- Model shows good correlation for majority of 41 COCs evaluated
  - Median: 0.28
  - Range: -0.32 to 0.60
- Plots shows results with best fit



- Model has poor fit for some COCs
  - Solubility
  - Decay (phthalates)
  - Ongoing sources
- Model goal isn't to predict concentration



- Model Concentrations consistent with measured concentrations
- Model goal isn't to predict concentration it's to predict SL exceedances

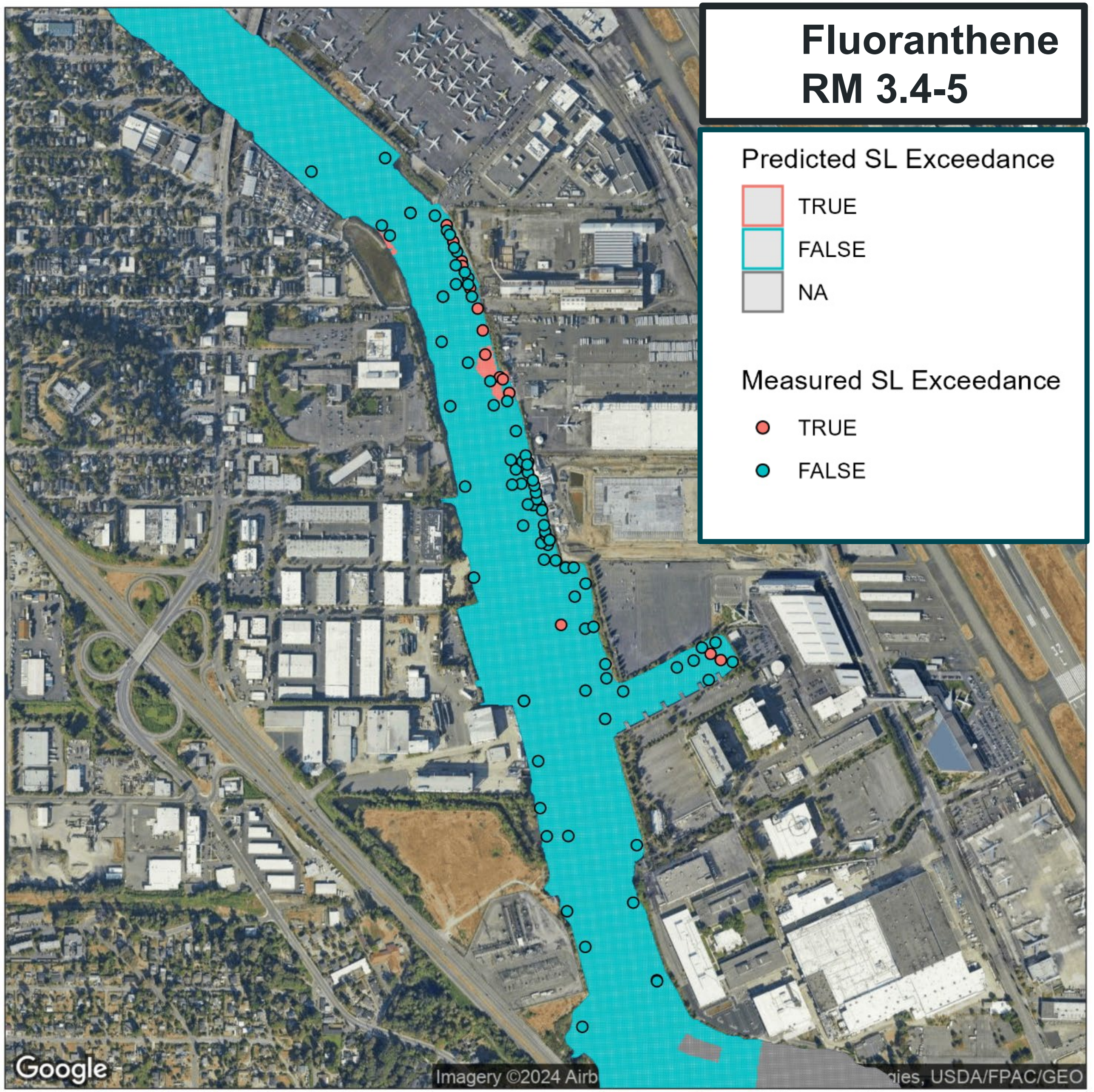


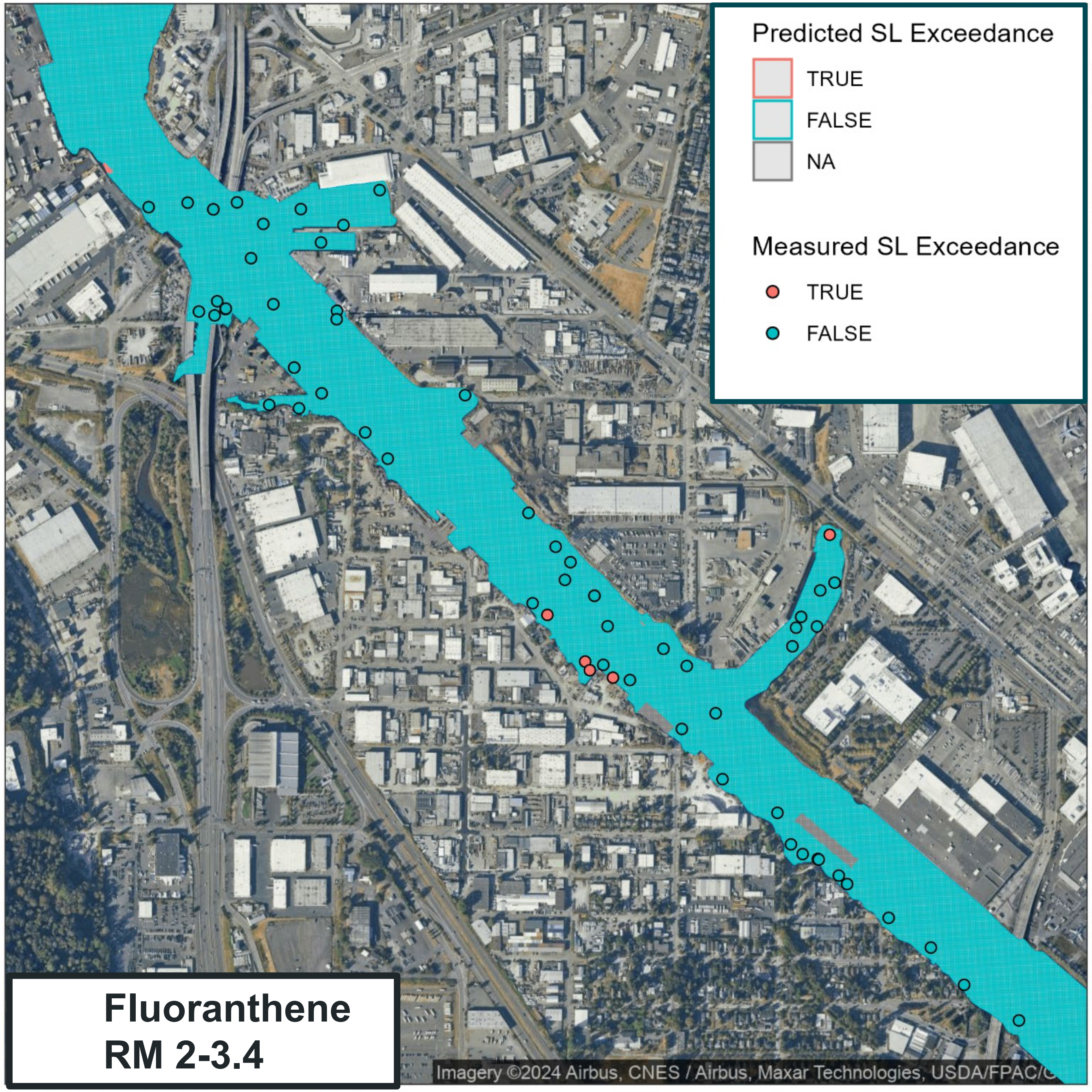
Exceedance Accuracy

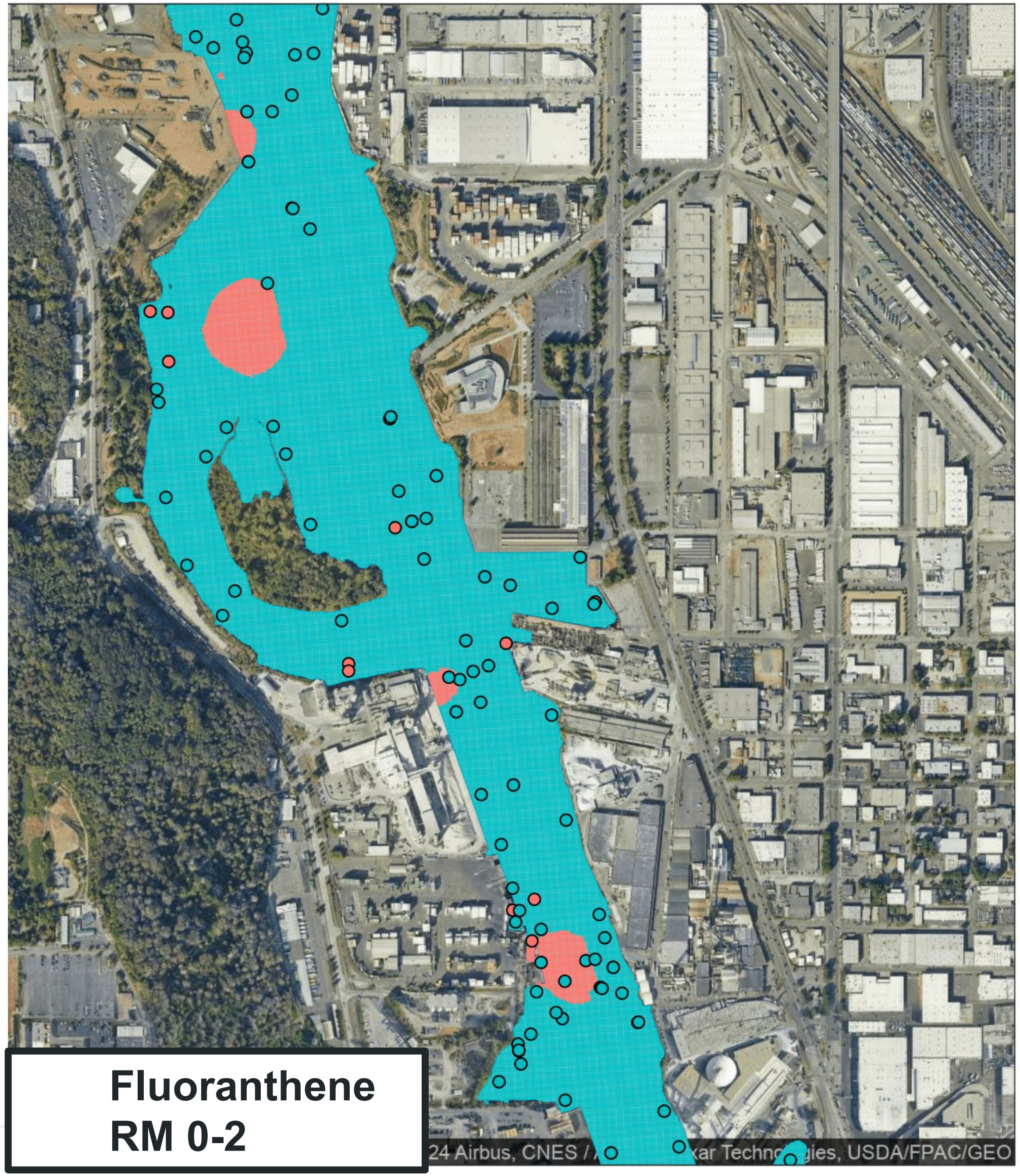
- Model identifies Screening level exceedance/non-exceedance in at least 88% of samples for 37 of 44 COCs
- Some COCs have lower Screening level error rates

Chemical	Correct	False Positive	False Negative
1,2-Dichlorobenzene	100%	0%	0%
1,4-Dichlorobenzene	100%	0%	0%
2-Methylphenol	100%	0%	0%
4-Methylphenol	100%	0%	0%
Acenaphthylene	100%	0%	0%
Di-n-butyl phthalate	100%	0%	0%
Di-n-octyl phthalate	100%	0%	0%
Diethyl phthalate	100%	0%	0%
Naphthalene	99%	0%	1%
Total LPAHs	98%	0%	2%
Copper	98%	0%	2%
Dibenzofuran	98%	0%	2%
Lead	98%	0%	2%
Anthracene	98%	0%	2%
2-Methylnaphthalene	97%	0%	3%
Acenaphthene	97%	0%	3%
n-Nitrosodiphenylamine	60%	33%	7%
Benzyl alcohol	58%	42%	0%
Total PCBs	48%	4%	48%
Benzoic acid	33%	67%	0%
Butyl benzyl phthalate	22%	77%	1%

- Model identifies areas of potential screening level exceedances
- This includes areas sparsely sampled




Predicted SL Exceedance
TRUE
FALSE
NA
Measured SL Exceedance
TRUE
FALSE
Fluoranthene
RM 2-3.4
Imagery ©2024 Airbus, CNES / Airbus, Maxar Technologies, USDA/FPAC/G


Fluoranthene
RM 0-2
24 Airbus, CNES / Maxar Technologies, USDA/FPAC/GEO

Model Refinements Can Improve Accuracy

- Using outfall-specific sediment and mass loading improves accuracy
- Modeling additional outfalls can capture important sources
- Incorporating groundwater upwelling (CapSIM) or other process can capture important processes
- Utilization of alternative hydrodynamic scenarios can assess sensitivity
- Potential improvements must balance speed and cost against increased accuracy and modeling goals

Combined Contaminant Transport Models Are Effective for Evaluating Recontamination

- Re-contaminant is an important issue, especially for expensive large scale sediment remediation projects
- While a screening level approach to individual sources can be helpful, a system-wide assessment, such as contaminant modeling, should be used
- There are many different approaches to contaminant modeling and their effectiveness depends on the system and modeling goals
- Combined contaminant transport models have been useful in predicting likelihood of re-contamination
- Design and/or improvements of combined contaminant transport models must balance speed, cost, and accuracy based on the goals of the model

Thank You

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