Use of PAH Compositional Analysis to Resolve Confounding Factors in Predictive and Empirical Sediment Toxicity

WEDA Midwest Chapter
Louisville, Kentucky
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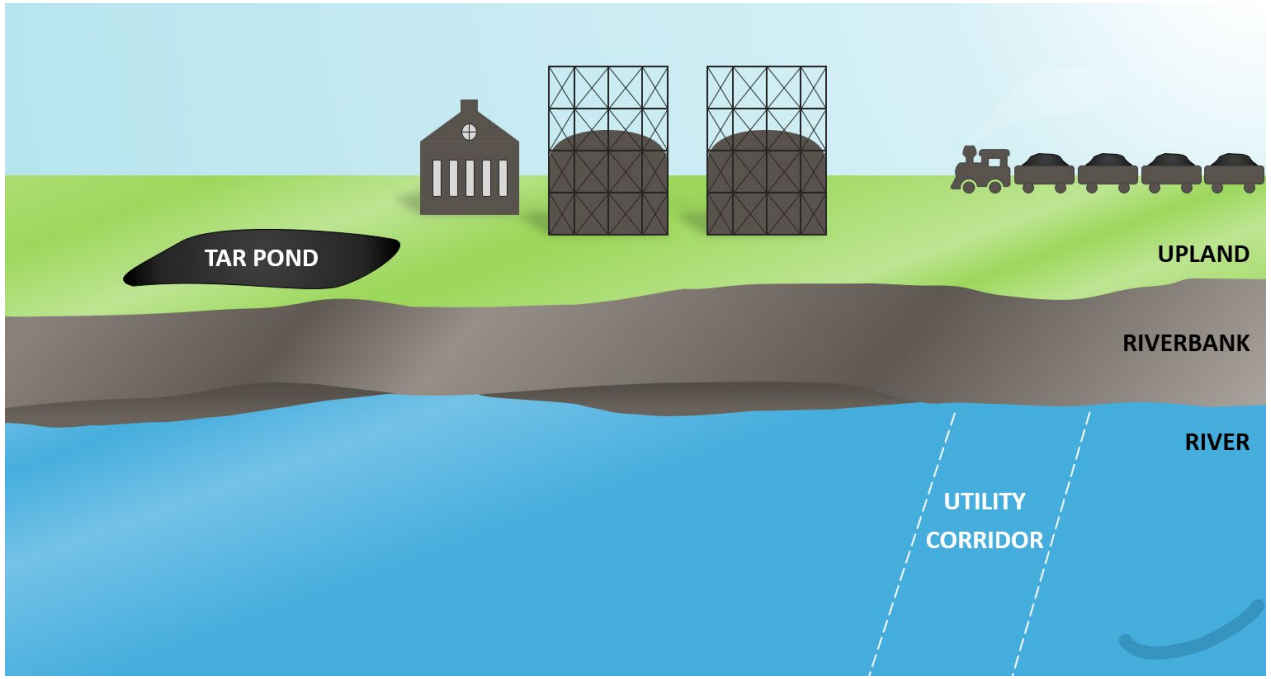
River Conceptual Site Model

- Former Manufactured Gas Plant
- Upland remediation and source control complete
- Situated on a major navigational waterway
- Elevation change from Upland to OHWM ~40 feet

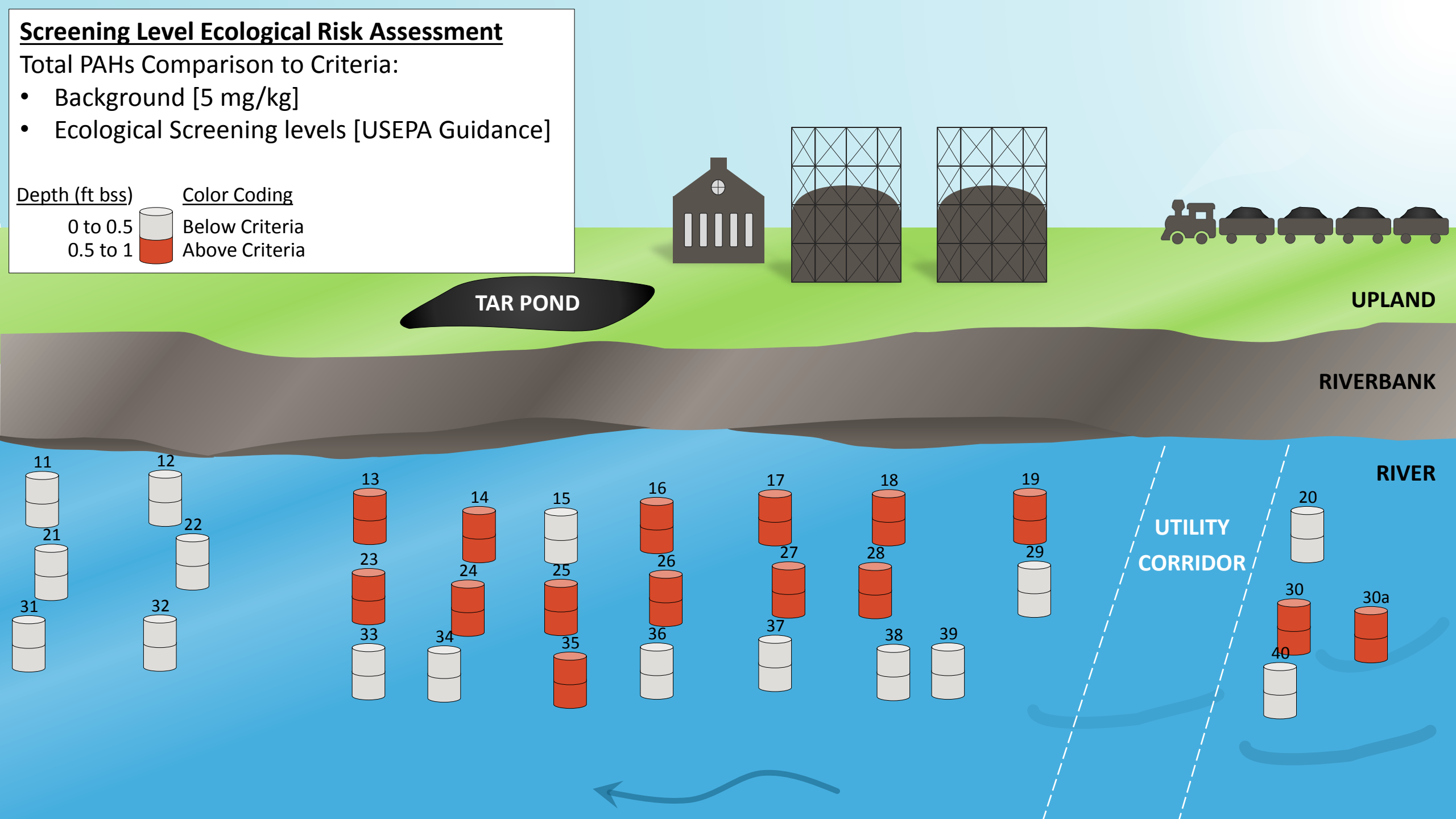


Primary Chemical of Concern in Sediment

PAHs

Primary Driver for Remediation

Risk to Benthic Macroinvertebrates


Screening Level Ecological Risk Assessment
Total PAHs Comparison to Criteria:
• Background [5 mg/kg]
• Ecological Screening levels [USEPA Guidance]
Depth (ft bss)
Color Coding
0 to 0.5
Below Criteria
0.5 to 1
Above Criteria
TAR POND
UPLAND
RIVERBANK
RIVER
UTILITY CORRIDOR
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Objective

Use multiple lines of evidence to characterize potential risks posed to the sediment benthic macroinvertebrate community by PAHs to determine whether a response is needed

Can the volume of sediments potentially requiring a response action be reduced?

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Typical Multiple Lines of Evidence Approach

Typically calculated for **all** sediment samples	Typically calculated or tested on a **subset** of sediment samples		
Predictive Modeling of Sediment Toxicity		**Tested Measurements of Sediment Toxicity**	
equilibrium sediment benchmark toxicity units (ESBTUs)	interstitial water toxicity units (IWTUs)	*In situ* toxicity tests	benthic macroinvertebrate community survey

When evaluating a response area, the typical approach is to focus on **toxicity testing**; however, toxicity testing is often performed on a **subset** of sediments

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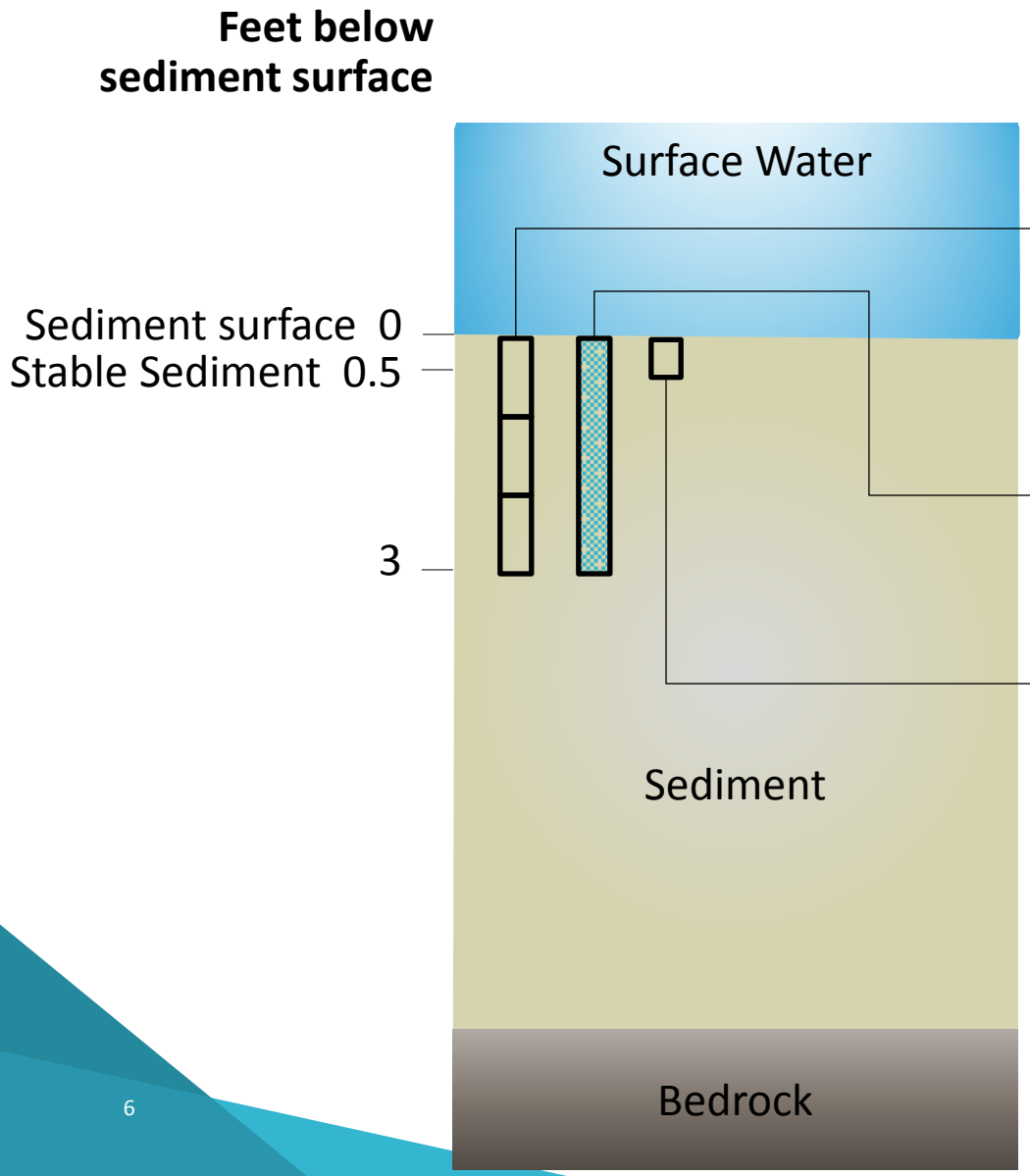
Data Collection

Bioactive Zone: Upper 0.5 feet of Sediment



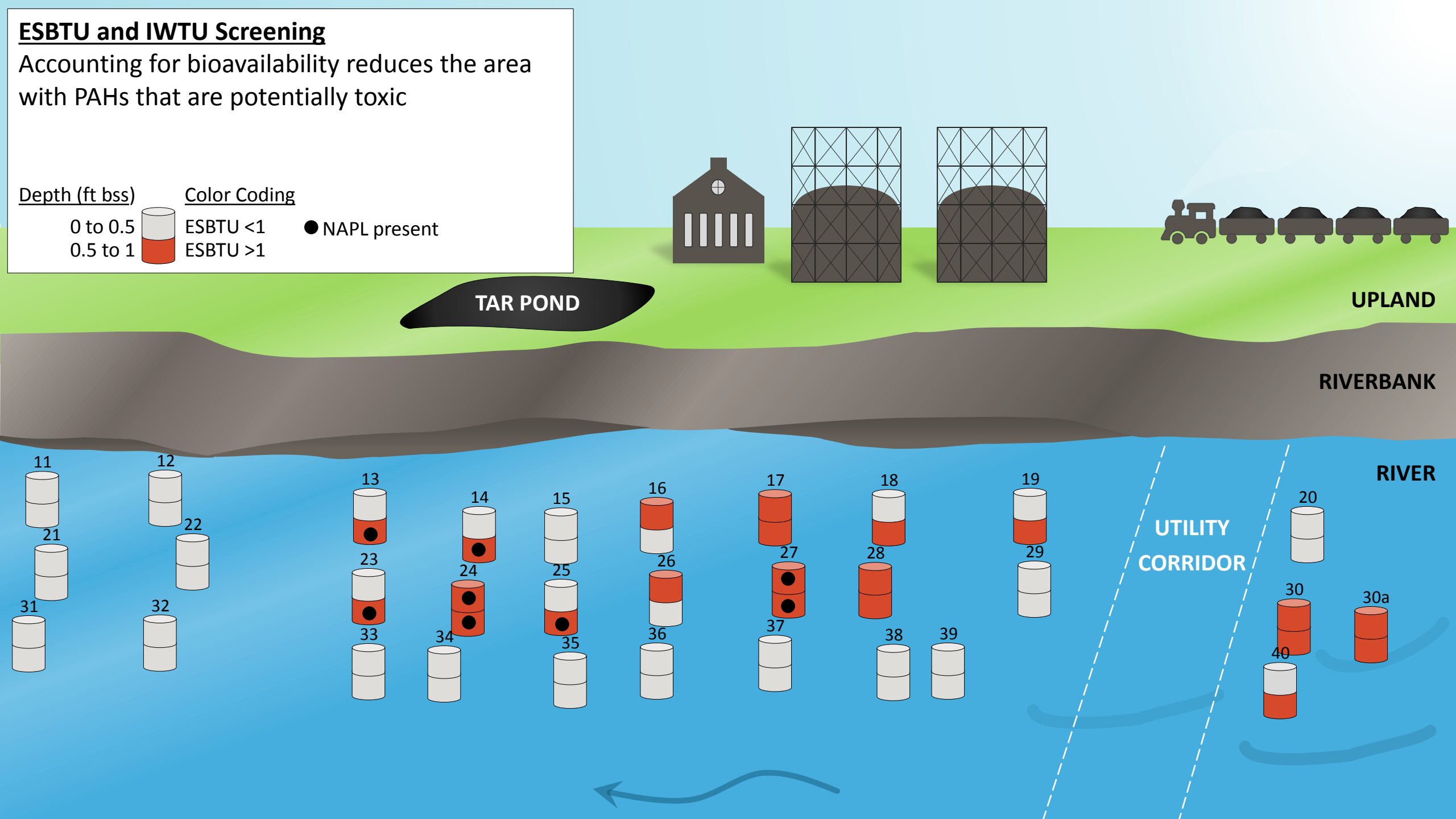
Sampling Methods

Indicators for Toxicity used in Line of Evidence Evaluation

Sediment Core Bulk
- PAHs, organic carbon → ESBTUs, 38 PAH concentrations
- Toxicity tests → Growth and Survival
  - amphipod *Hyalella azteca*
  - larval insect *Chironomus dilutus*

Pore Water extracted from Sediment
- PAHs, organic carbon → IWTUs

Sediment Grab
- PAHs, organic carbon → ESBTUs, 38 PAH concentrations
- Toxicity tests → Growth and Survival
- Benthic macroinvertebrate community survey → Species Abundance and Diversity


ESBTU and IWTU Screening
Accounting for bioavailability reduces the area with PAHs that are potentially toxic
Depth (ft bss)
Color Coding
0 to 0.5
0.5 to 1
ESBTU <1
ESBTU >1
NAPL present
TAR POND
UPLAND
RIVERBANK
RIVER
UTILITY CORRIDOR
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Project Specific Lines of Evidence

Station	Total PAHs (mg/kg)	ESBTU	PAH Weathering Ratio	Tested Toxicity				Benthic Community Assessment	Outcome
				Hyalella azteca		*Chironomus dilutus*			
				Survival (significant decrease)	**Growth** (significant decrease)	**Survival** (significant decrease)	**Growth** (significant decrease)		
17	219	1.7	0.59	No	No	No	No	No	No adverse effects
18	726	2.0	0.41	No	No	No	No	No	No adverse effects
30	120	13	0.57	No	**Yes**	No	No	NA	Negligible
28	765	2.5	0.33	**Yes**	No	No	**Yes**	No	Minimal Effects
25	229	12	3.82	**Yes**	**Yes**	**Yes**	**Yes**	NA	Adverse Effects
25	204	33	4.53	**Yes**	**Yes**	**Yes**	**Yes**	NA	Adverse Effects

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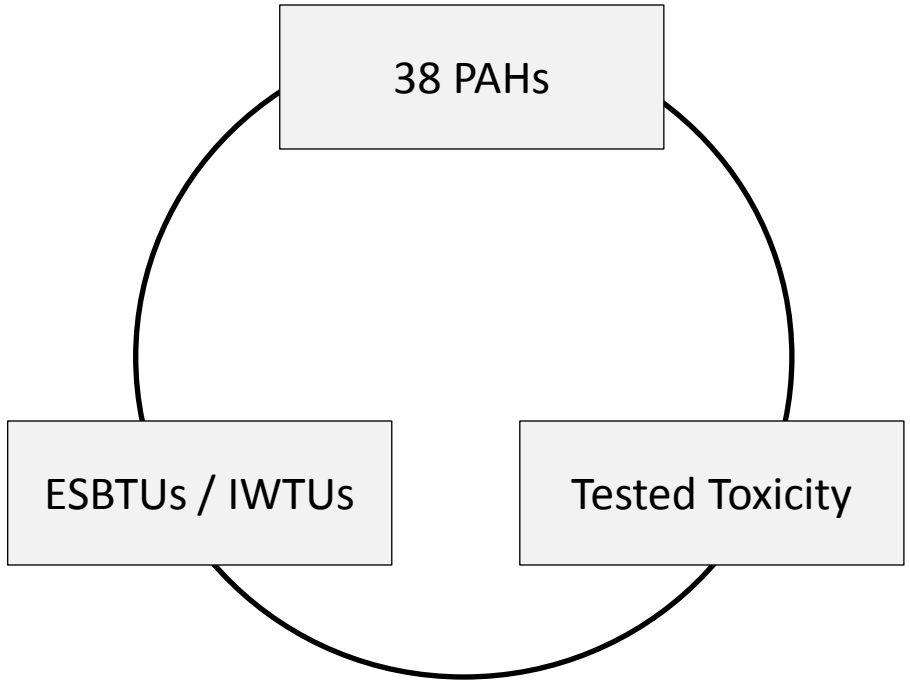
Project Specific Lines of Evidence Assessment



Correlations

No trends with bulk sediment PAH concentrations and toxicity test results

General trends with ESBTUs / IWTUs and toxicity test results

Distinct trends with PAH composition, ESBTUs, and toxicity test results

Used PAH compositional evaluations (i.e., **PAH weathering ratio**) to correlate toxicity testing outcomes with PAH chemistry and ESBTUs

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PAH Weathering Ratio

$$PAH_{\text{weathering ratio}} = \frac{\sum \text{Low molecular weight PAHs [2- and 3-rings]}}{\sum \text{High molecular weight PAHs [4-, 5- and 6-rings]}}$$

Low molecular weight PAHs: more toxicity and other adverse effects to some organisms, tend to have higher solubility in water and are therefore more bioavailable

High molecular weight PAHs: significantly less toxic to a wide variety of aquatic organisms

$PAH_{\text{weathering ratio}} > 1$ expected to exhibit higher toxicity

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.11). Accessed at: https://www.pwrc.usgs.gov/eisler/CHR_11_PAHs.pdf.

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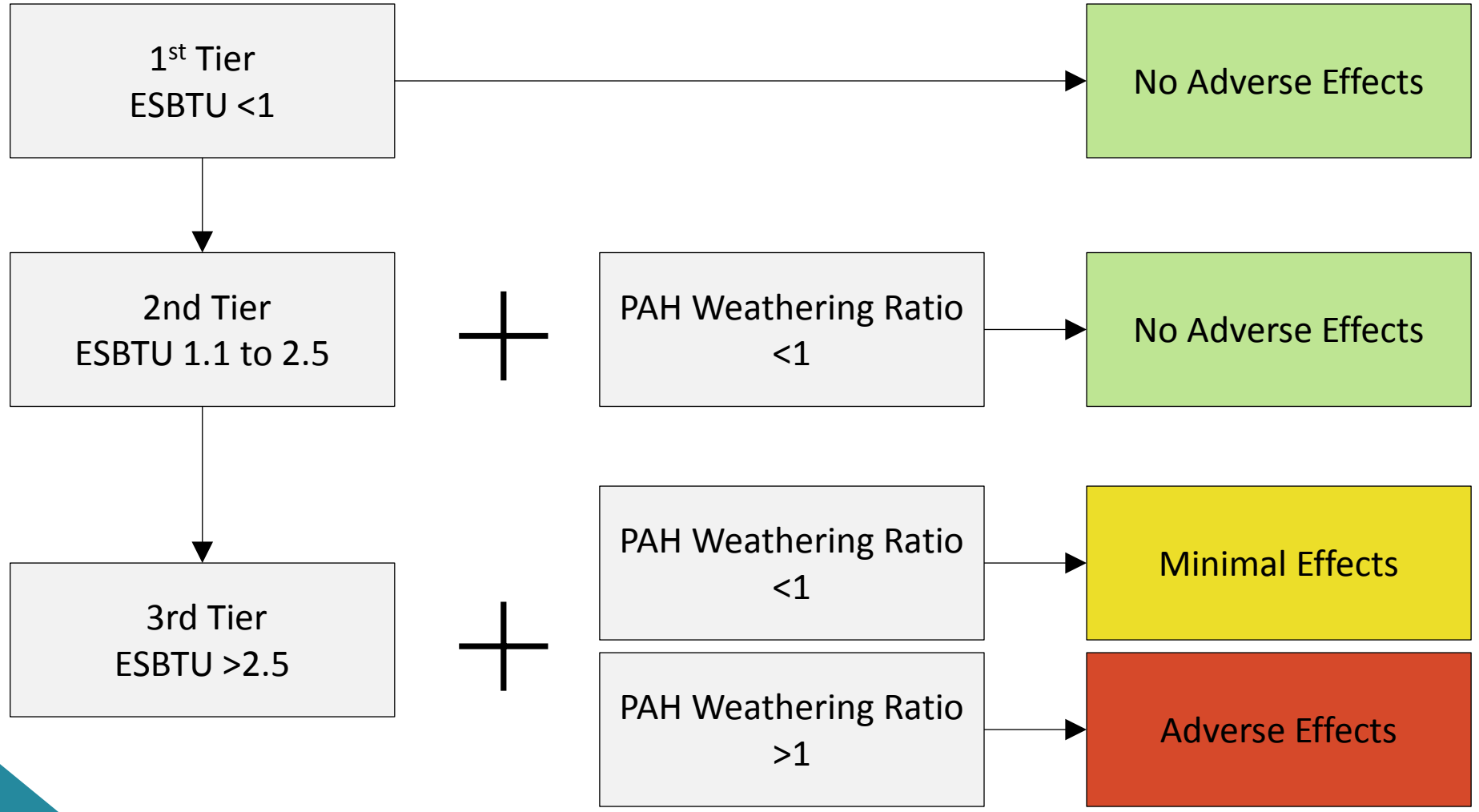
Multi-tiered Approach with Project Specific Lines of Evidence

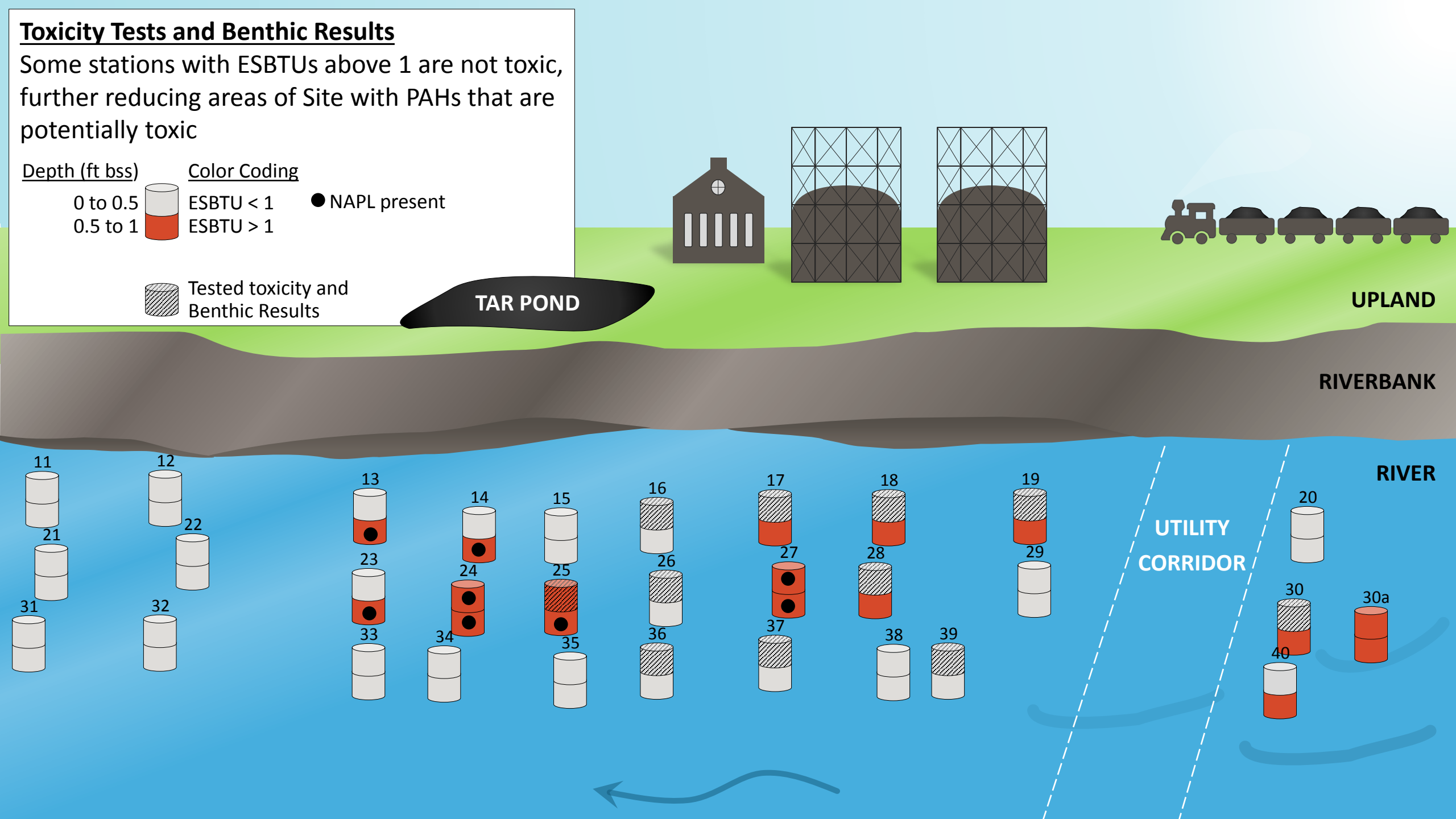


Not PAH Related

Poster Session A5 Contaminant Forensics

Applying PAH Source Forensics to Refine a Conceptual Site Model

Titania Ng
Haley & Aldrich, Inc.


Toxicity Tests and Benthic Results
Some stations with ESBTUs above 1 are not toxic, further reducing areas of Site with PAHs that are potentially toxic
Depth (ft bss)
Color Coding
0 to 0.5
0.5 to 1
ESBTU < 1
ESBTU > 1
NAPL present
Tested toxicity and Benthic Results
TAR POND
UPLAND
RIVERBANK
RIVER
UTILITY CORRIDOR
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PAH Weathering Ratio
Samples with PAH weathering ratios above 1 have adverse effects on benthic macroinvertebrates
Depth (ft bss)
Color Coding
0 to 0.5
0.5 to 1
ESBTU < 1
PAH Weathering Ratio >1
PAH Weathering Ratio <1
Tested toxicity and Benthic Results
NAPL present
TAR POND
UPLAND
RIVERBANK
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UTILITY CORRIDOR
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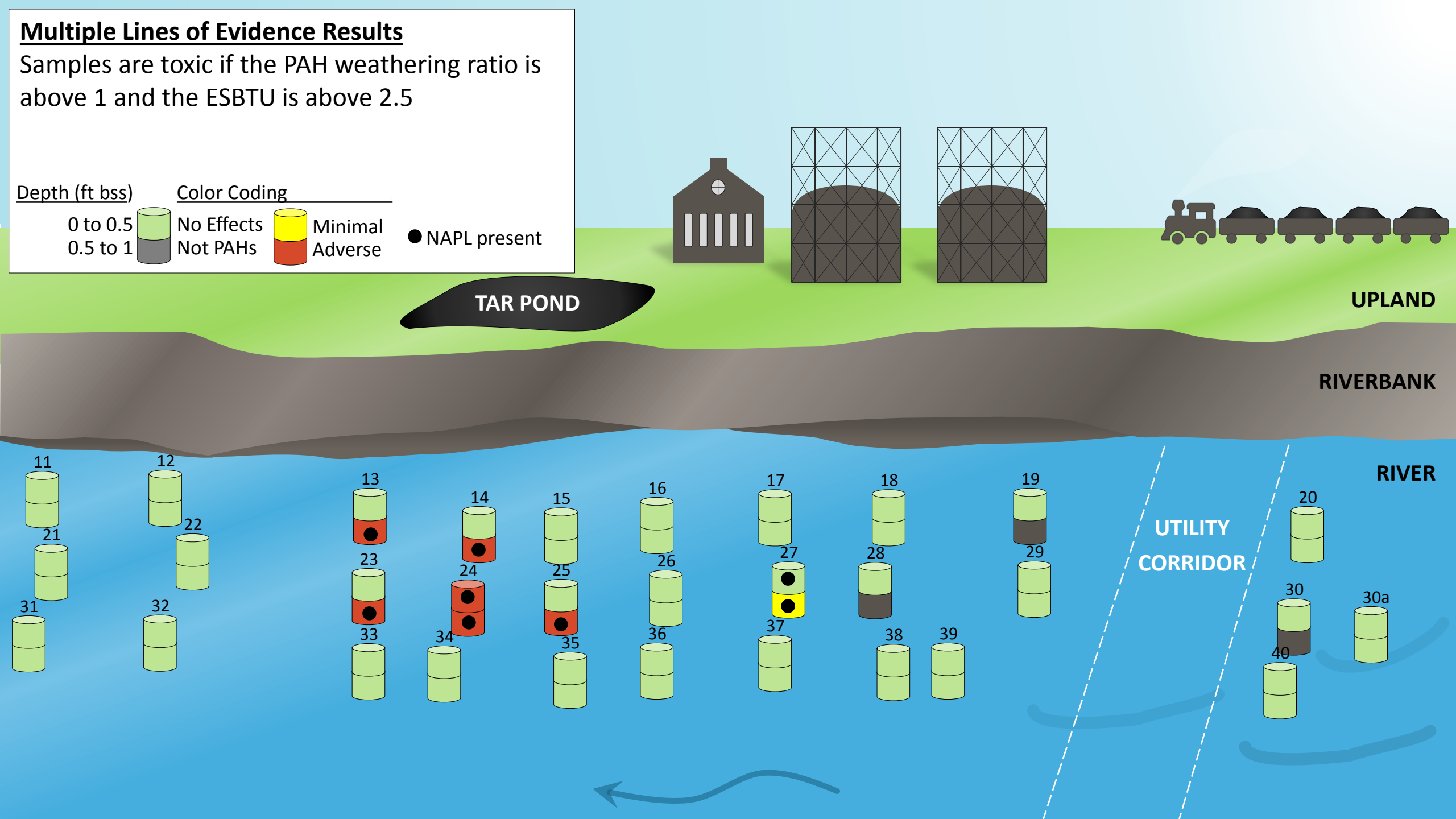
Multiple Lines of Evidence Results
Samples are toxic if the PAH weathering ratio is above 1 and the ESBTU is above 2.5
Depth (ft bss)
0 to 0.5
0.5 to 1
Color Coding
No Effects
Not PAHs
Minimal
Adverse
NAPL present
TAR POND
UPLAND
RIVERBANK
RIVER
UTILITY CORRIDOR
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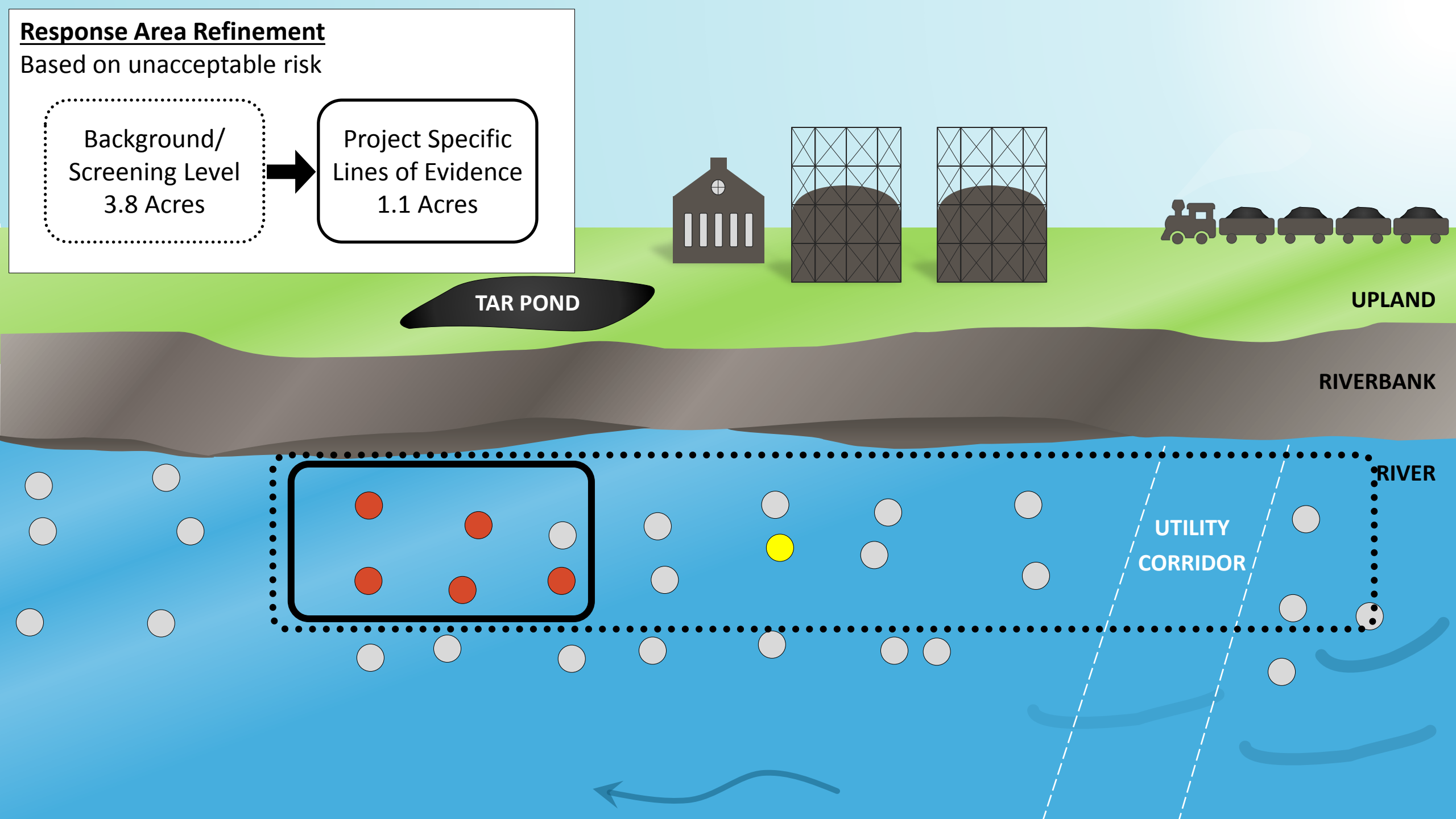
Response Area Refinement

Based on unacceptable risk

Background/
Screening Level
3.8 Acres

→

Project Specific
Lines of Evidence
1.1 Acres



Conclusions

Sediment toxicity was sensitive to PAH weathering ratio

- higher PAH weathering ratios were toxic when ESBTUs were also above 2.5
- lower PAH weathering ratios were not toxic at ESBTUs above 1

Collectively, the multi tiered project specific multiple lines of evidence evaluation was used to refine and reduce sediments that may require a response action

Remediation design can be based on a measure of ESBTU and PAH weathering ratio, not total PAH concentration

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