Appendix A
Supplemental Data Evaluation

Duck and Otter Creek Feasibility Study
Appendix A

Supplemental Data Evaluation

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Contents

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Acronyms and Abbreviations

AVS	acid volatile sulfide
DELT	deformities, eroded fins, lesions, or tumors
DGI	Duck and Otter Creeks Gap Investigation
DRO	diesel range organics
ERDC	Engineer Research and Development Center
ESBTU	equilibrium partitioning sediment benchmark toxic units
FCV	final chronic value
foc	fraction organic carbon
GLLA	Great Lakes Legacy Act
GLNPO	Great Lakes National Program Office
IBI	Index of Biotic Integrity
K_{oc}	organic carbon–water partition coefficient
L/kgOC	liters per kilogram organic carbon
MDEQ	Michigan Department of Environmental Quality
µg/L	micrograms per liter
µmol/g	micromoles per gram
µmol/gOC	micromoles per gram organic carbon
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
OMZA	outside mixing zone area
PAH	polycyclic aromatic hydrocarbon
PBT	persistent, bioaccumulative, and toxic pollutants
PCB	polychlorinated biphenyl
PEC	Probable Effect Concentration
PHWH	Primary Headwater Habitat
QHEI	Qualitative Habitat Evaluation Index
RCRA	Resource Conservation and Recovery Act
SEM	simultaneously extracted metals
SVOC	semivolatile organic compound
TOC	total organic carbon
TRI	Toxic Release Inventory

TU	toxic units
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound
WQC	water quality criteria

1 Introduction

Duck and Otter Creeks are small streams that flow in parallel through a primarily urban and industrial area located in the cities of Toledo and Oregon, Ohio. Both streams have historically been affected by multiple stressors, including habitat modifications and chemical contamination. The focus of this Appendix is sediment contamination in Duck and Otter Creeks and its relationship to observed biology. This evaluation is intended to support the identification of geographic areas and contaminants that warrant sediment management measures, as well as areas and contaminants requiring no such measures. This evaluation builds upon data analyses presented in the *Duck and Otter Creeks Great Lakes Legacy Act Data Gap Investigation* (DGI) report (Cardno Entrix 2012).

The DGI report included the following recommendations:

- Further evaluate potential remedies for Segment A of Otter Creek in a subsequent phase of the project.
- Further evaluate the combined 2007 and 2010 data sets for the remaining stream sections in a subsequent phase of the project.

This supplemental data evaluation addresses the second of these recommendations. It also integrates data collected from the confluence areas at the mouths of Duck and Otter Creeks, as well as data from several smaller sampling events.

A key component of the DGI report was the evaluation of potential causes of sediment toxicity, based on relationships between chemical exposures, toxicity test results, and benthic invertebrate community observations (i.e., sediment triad data). In the sediment triad study, observed toxicity was well explained based on chemical concentrations in sediment porewater, but not based on bulk sediment chemistry results. The present supplemental data evaluation expands the analysis of relationships between sediment and porewater toxicity and chemistry using data presented in the *Data Evaluation Report for Duck and Otter Creeks Confluence Sediment Investigation* (Weston 2012a) and the *Technical Memorandum for October 2011 Otter Creek Confluence Data* (Weston 2012b).

While porewater chemistry results are a useful tool for predicting sediment toxicity, sediment porewater has been analyzed in only a fraction of the Duck and Otter Creeks sediment samples that have been analyzed for bulk chemistry. Thus, this Appendix includes an evaluation of methods to extrapolate the sediment triad results to the larger bulk sediment data set, to aid the characterization of sediment contamination in the creeks.

1.1 Objectives

Specific objectives of this supplemental data evaluation are as follows:

- Compile sediment chemistry results from multiple recent sampling events (2006-2011) in a single database, with particular focus on the 2007 and 2010 data for Duck and Otter Creeks and the 2010 and 2011 data for the confluence areas.

- Review the site-specific relationship between porewater concentrations of polycyclic aromatic hydrocarbons (PAHs) and sediment toxicity determined for Otter Creek using the combined DGI and confluence area data sets

- Evaluate the chemical "fingerprints" of PAH mixtures in Duck and Otter Creek sediments to support the assessment of the biologically available component of PAHs and subsequent assessment of potential ongoing releases

- Develop a means to apply the porewater-based exposure-response relationship for PAHs to areas where only bulk sediment data are available

- Define the horizontal and vertical extent of impacted sediment attributed to biologically available petroleum hydrocarbons, focusing on PAHs

- Use the compiled data from recent sampling events to verify whether other chemicals—specifically metals, polychlorinated biphenyls (PCBs), semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and pesticides—are insignificant contributors to sediment toxicity in Duck and Otter Creeks, as preliminarily concluded based on DGI results

1.2 Appendix Organization

The remainder of this Appendix is organized in the following sections:

- 2. Data Compilation. Sediment and biota tissue data sets and data handling methods are described.

- 3. Sediment Toxicity. Sediment toxicity test results from the 2010-2011 DGI and confluence area sampling events are summarized, and their consistency with biological community observations and past toxicity test results is discussed.

- 4. PAHs and Petroleum Hydrocarbons. This section defines the site-specific relationship between bioavailable PAH exposures and sediment toxicity, considering multiple lines of evidence. The relationship between porewater PAH exposures and bulk sediment parameters—notably petroleum hydrocarbon measurements—is evaluated to aid interpretation of the larger bulk chemistry data set, and the horizontal and vertical extent of predicted sediment toxicity is identified.

- 5. Metals. Site-specific lines of evidence indicating low metal bioavailability are discussed, including porewater analyses, measurements of acid volatile sulfide (AVS) and simultaneously extracted metals (SEM), and biota tissue analyses. For key metals, supplemental evidence from the scientific literature is also assembled to shed light on cause-effect relationships between bulk sediment total metal concentrations and sediment toxicity. Consistency of metal concentrations measured in 2010-2011 with earlier analyses is discussed.

- 6. PCBs. The potential for adverse biological effects due to PCBs in Duck and Otter Creeks is evaluated based on bulk sediment chemistry and biota tissue data.

- 7. Other Chemicals. This section briefly discusses concentrations of SVOCs and pesticides and outlines why these chemicals are not significant contributors to sediment toxicity in Duck and Otter Creeks.

- 8. Summary and Conclusions. Risk drivers are identified, and the extent of predicted sediment toxicity is summarized.

- 9. References

2 Data Compilation

The current database is comprised of several data sets, as described below. The primary focus of this supplemental data evaluation is the data collected under sponsorship of the U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO) in 2007 and 2010-2011. Additional data sets are also included for completeness. Sediment sample locations are shown in Figure 2-1.

- Great Lakes Legacy Act (GLLA) Sediment Sampling. In 2010, an investigation was undertaken to fill data gaps in previous investigations of Duck and Otter Creek sediments (Cardno Entrix 2012). The DGI sampling was performed by Weston Solutions, Inc., on behalf of the Duck and Otter Creek Industrial Partners (i.e., BP-Husky, Chevron, Sunoco, and Pilkington North America) and the U.S. Environmental Protection Agency (USEPA) Great Lakes National Program Office (GLNPO). Concurrently, GLNPO also initiated a separate investigation of sediment quality in the confluence areas where Duck Creek joins the mouth of the Maumee River and Otter Creek joins Maumee Bay. The confluence area sampling was conducted by Weston in 2010 and 2011 (Weston 2012a,b). Collectively, the GLLA 2010-2011 data set includes 645 sediment, 120 porewater, and 8 invertebrate tissue samples analyzed for chemical constituents. Sediment toxicity testing was performed for 49 sediment samples, and the benthic invertebrate community was characterized at 13 locations. The DGI sampling also included two urban comparison stream locations, which were sampled for all DGI parameters; no comparison locations were sampled in the confluence area sampling program.

- U.S. Fish and Wildlife Service (USFWS) Fish Sampling. In August 2010, the USFWS collected fish from Duck and Otter Creeks for tissue analysis. In addition to representing the creeks, one of the sampling zones extended into the Otter Creek confluence area. The six areas sampled are shown in Figure 2-2. Analytical data for 53 fish tissue samples are available from two analytical results reports (USFWS 2011). Because the data are not yet available in database format, only selected parameters were extracted from the USFWS reports for the current analysis.

- Westover Landfill Sediment Sampling. On behalf of USEPA's Region 5 Emergency Response Branch, Weston investigated environmental conditions at the Westover Landfill, located adjacent to Otter Creek (Weston 2009). The investigation, conducted in August 2009, included collection of two sediment samples from locations upstream and downstream of the Westover Landfill Site.

- Ohio EPA Sediment Sampling. Ohio EPA collected six sediment samples from three locations in upper Duck Creek in 2008. In 2006, Ohio EPA collected seven sediment samples from four locations in Otter Creek. Ohio EPA also evaluated fish and invertebrate communities at several of the sample locations (Ohio EPA 2010).

- GLNPO 2007 Sediment Sampling. On behalf of GLNPO, SulTRAC conducted sediment sampling from Duck and Otter Creeks in 2007 under a grant awarded to the Duck and

Otter Creeks Partnership. A total of 62 sediment samples were collected, and a subset of samples was tested for toxicity (SulTRAC 2007).

- Envirosafe Sediment Sampling. As part of a Resource Conservation and Recovery Act (RCRA) Facility Investigation for Envirosafe's Otter Creek Road facility (ENVIRON 2009), ENVIRON collected sediment samples from Otter Creek adjacent to the Millard Road Landfill. Sediment sampling was conducted between 2002 and 2007. To best represent current conditions, the present evaluation incorporates Envirosafe data from 2006-2007. The data set includes 27 sediment samples from 11 locations in Otter Creek.

The compiled data set is contained in three Microsoft Access tables (results, samples, and locations) with two auxiliary tables (chemicals and units) to aid in database queries. Complete analytical results are presented in Attachment 1.

Certain data corrections, assumptions, and discrepancies are noted as follows:

- Pyrethroid pesticide results initially labeled as collected from location OC-9 in the DGI data set were corrected to location OC-9-10.

- Data validator results were used for the GLNPO 2007 data set. The sediment total organic carbon (TOC) data validator result for sample S12-DC-12 was greater than 100%, so the laboratory result was used for calculations.

- The Westover Landfill and Ohio EPA 2008 data sets did not indicate whether sediment concentrations were presented on a dry weight or wet weight basis. Dry weight basis was assumed.

- The Ohio EPA 2006 sediment data for Otter Creek were not available from the Division of Surface Water database and were extracted from laboratory reports if available, or from Ohio EPA's (2010) report. For organic compounds, Ohio EPA (2010) presented only detected results; non-detected concentrations are thus omitted from the compiled database.

- Analytical data for the GLNPO 2007 sediment samples were obtained in database form from TetraTech. The database should have corresponded with the results presented by SulTRAC (2007), but a discrepancy was noted for two metals. SulTRAC (2007) reported total metal results for the "RCRA 8" metals, which include silver and do not include zinc. However, the database contained results for total zinc and not for silver. The version of the data provided in the TetraTech database is used in this supplemental data evaluation.

Summary statistics were calculated for all detected chemicals; results are presented by chemical class in subsequent sections of this Appendix. Field duplicate and split samples and non-reportable (rejected) results are not included in calculations.

Non-detected concentrations were calculated as half the detection limit. If multiple limits were given (e.g., method detection limit, reporting limit), the maximum limit was used for this purpose.

The treatment of non-detected concentrations in this supplemental data evaluation is different than that applied in previous interpretations of the GLLA 2010-2011 data, where non-detects were excluded from calculations (Cardno Entrix 2012, Weston 2012a,b). As a result, calculations of total PAH concentrations and PAH toxic units may differ (slightly) between reports.

3 Sediment Toxicity

Direct toxicity is the primary environmental concern related to sediment contaminants in Duck and Otter Creeks due to the characteristics of the primary chemical contaminants (i.e., PAHs and metals). Specifically, PAHs and most metals have relatively limited bioaccumulation potential. Contaminants that can biomagnify through the food web are not prevalent at concentrations of concern in Duck and Otter Creeks (see Sections 5 through 7).

This section summarizes recent laboratory toxicity testing with Duck and Otter Creek's sediment samples (Section 3.1) and evaluates the site-specific utility of laboratory toxicity tests as predictors of biological effects in the field (Section 3.2). Sediment toxicity test results from the GLLA 2010-2011 sampling are used preferentially in this analysis based on data quality concerns with respect to the 2007 sediment toxicity tests, as discussed in Section 3.3.

3.1 2010-2011 Sediment Toxicity Testing

Sediment toxicity testing was conducted in 2010-2011 using the sediment-dwelling larvae of the midge, *Chironomus dilutus*, exposed to surface sediment samples. Sediment toxicity testing was performed by the U.S. Army Corps of Engineers' Engineer Research and Development Center (ERDC). Midge survival and growth were measured after 10 days' exposure to site sediment. These endpoints were used to calculate biomass, which represents the total mass of surviving organisms at the end of the test, divided by the number of test organisms present at test initiation. This supplemental data evaluation focuses on the biomass endpoint because (1) it integrates survival and growth endpoints, and (2) it is relevant to both persistence of midge populations and availability of midge biomass as prey for fish.

Toxicity test results are summarized in Table 3-1. Statistical analyses of the toxicity test results were performed by ERDC in all cases. For a subset of the confluence-area test groups, Weston also performed statistical analyses using a different software program than ERDC (Weston 2012a). Weston's analyses identified a larger number of results as significantly different than the respective controls compared to ERDC's analyses. Table 3-1 identifies whether findings of statistical significance were determined by ERDC, Weston, or both. Only a small number of locations were identified as toxic based only on Weston's statistical analysis, and when evaluated individually, these locations are not expected to result in material differences in the scope of planning for sediment management measures. As discussed further in Section 4, this supplemental data evaluation relies on the magnitude of midge biomass reduction to identify toxicity thresholds for PAH exposure, rather than determinations of statistical significance. Therefore, specific differences between the ERDC and Weston analyses do not affect the conclusions of the exposure-response evaluation. Table 3-1 also shows biomass results as a percentage of the corresponding control result; this facilitates comparisons among toxicity test groups because the batches of toxicity test organisms differed in organism weights.

In addition to sediment samples from Duck and Otter Creeks, the DGI program included sediment toxicity testing for two urban comparison locations, Amlosch Ditch and Grassy Creek. Sediments from these locations were not toxic.

Upon test completion, indigenous predatory flatworms (planaria) were observed in several sediment samples collected for the DGI program. Based on the relationship between flatworm presence and midge survival in individual replicate test chambers, it was apparent that the flatworms tended to eat the test organisms. Therefore, all test replicates containing flatworms were excluded from the data analysis. Sufficient test replicates without flatworms were available to support statistical analyses, except in the case of the two urban comparison location samples which were subsequently retested successfully. Flatworms were not observed in the confluence area sediment samples.

The spatial distribution of toxicity test results is shown in Figure 3-1. This figure depicts both the magnitude of differences in midge biomass (symbol color) and whether observed differences were determined to be statistically significant (symbol shape). Statistically significant reductions in midge biomass were generally limited to Otter Creek downstream of Consaul Street and portions of the Otter Creek confluence area. Only one sediment sample collected from Duck Creek exhibited statistically significant toxicity (location DC-25, just above the Maumee River confluence), and the magnitude of effect at this station was limited (biomass was 69% of control).

At two locations in upper Duck Creek, midge biomass was 69% of control (DC-6/7) and 54% of control (DC-11/12), but there was no statistically significant difference between these results and those of the paired control due to high variability among test replicates. As evaluated in subsequent sections of this Appendix, chemical concentrations in DC-6/7 sediment were not notably elevated. Sediment from DC-11/12 contained the highest total arsenic concentration measured in 2010-2011, but the corresponding porewater arsenic concentration was well below the designated screening value, indicating a low likelihood of effects due to arsenic. In any event, Duck Creek was dry in the vicinity of DC-11/12 at the time of sampling, such that the area could not have supported benthic invertebrates in any case. The lack of statistically significant differences between these sample results and those of the control indicates that the differences in mean biomass could be a result of random variation. Indeed, the control biomass was much higher than in any other toxicity test group,[1] suggesting that the control performance was on the high end of the normal range of random variability, which would increase the magnitude of differences with test samples when results are control-normalized.

3.2 Consistency with Biological Community Observations

Sediment toxicity tests are a tool to understand potential effects on benthic invertebrate communities. Toxicity tests have the advantage of isolating sediment-related effects from the effects of physical habitat and water quality characteristics. On the other hand, toxicity that is observable under laboratory conditions is not always manifested in the field. Therefore, benthic invertebrate community observations can serve as a second line of evidence to help understand whether toxicity tests are useful for predicting effects in the field on a site-specific basis.

[1] Sample DC-11/12 was tested together with Control 3 (see Table 3-1). The results listed for Control 5 are identical to those for Control 3, because these were actually the same control sample. This toxicity test group included both DGI and confluence area samples, and the test results were thus presented in two separate reports.

Benthic macroinvertebrate community composition was characterized along with sediment chemistry and toxicity for 13 DGI sediment triad locations. Consistency between toxicity test results and benthic community characteristics for this data set is discussed below (Section 3.2.1). In addition, Ohio EPA measurements of invertebrate and fish community quality provide another line of evidence for consideration (Section 3.2.2), although the Ohio EPA data are not directly paired with laboratory toxicity tests.

3.2.1 2010 Benthic Macroinvertebrate Community Sampling

Benthic community data were collected for the DGI including for two urban comparison locations. No benthic community data were collected for the GLNPO 2007 creek sampling or the 2010-11 confluence sampling. As demonstrated in the DGI and further explained in this section, there is an apparent correlation between measured biological effects in the creeks and benthic community metrics. As is evident from this discussion, it is not necessary or intended to extend the findings for Duck and Otter Creeks to the confluence areas.

The comparisons between sediment toxicity test results and benthic invertebrate community composition in the sediment triad samples are detailed in the DGI report (Cardno Entrix 2012). The benthic community evaluation focused on three metrics: taxa richness (i.e., number of distinct types of invertebrates), the percentage of invertebrates characterized as sensitive to anthropogenic disturbance, and the percentage of invertebrate characterized as tolerant to anthropogenic disturbance. To further clarify the relationship between laboratory toxicity and benthic community quality, this supplemental data evaluation includes one additional data interpretation step. Specifically, the three benthic metrics are reduced to a single score through a simple ranking procedure.

Benthic ranks were calculated separately for each metric, as shown in Table 3-2. For each metric, the sample results were sorted from high to low, and ranks were assigned such that the most favorable result received a rank of 1, and the least favorable received a rank of 13. Identical results were given the same rank (e.g., locations tied for ranks 3 and 4 both received a rank of 4). The average of the ranks for the three metrics was then used to represent relative benthic community quality.

The ranking procedure makes no assumptions as to what metric results should be expected or desired; it merely compares observed results within the DGI data set. Although Ohio EPA has established standard invertebrate community sampling protocols, alternative methods were necessary for the DGI sampling because Ohio EPA's standard artificial substrate sampling technique is not effective in streams as small as Duck and Otter Creeks. Therefore, it is not possible to compare quantitatively to ecoregional reference conditions as determined by Ohio EPA. Ohio EPA's qualitative interpretation of benthic community quality in Duck and Otter Creeks is discussed in Section 3.2.2.

The average benthic ranks for Duck and Otter Creeks form three groups of locations (Table 3-3). The best relative benthic community quality (ranks ranging from 2 to 6) was observed in Duck Creek, the urban comparison locations, and the upstream-most Otter Creek sample location. The poorest quality (ranks ranging from 11 to 13) was observed in lower Otter Creek downstream of Millard Avenue. Intermediate benthic quality (ranks ranging from 9 to 10) was

observed in the remainder of Otter Creek. No benthic community data were collected in the confluence areas.

As shown in Table 3-3, the toxicity test results and porewater PAH toxic units (TU) (discussed further in Section 4) show reasonably good agreement with the benthic ranks for the area of lowest benthic community quality. The difference between the areas of best and intermediate benthic quality is not well explained based on these variables, however. One possible explanation of benthic quality differences between middle Otter Creek and the other investigated creeks is the presence of more than 50 stormwater outfalls in this area, which likely have a profound effect on the stream's hydrology. Such a large input of stormwater would be expected to create flashy conditions where sudden increases in water flow tend to disrupt the stream substrate and wash benthic organisms downstream. Overall, the benthic invertebrate community results for Otter Creek are consistent with the occurrence of sediment toxicity in downstream portions of Otter Creek.

3.2.2 2006-2008 Ohio EPA Biomonitoring

Ohio EPA evaluated fish and invertebrate community quality at two Duck Creek locations (2008) and four Otter Creek locations (2006). Although Ohio EPA's standard methodology for assessing benthic invertebrate communities cannot be applied in streams as small as Duck and Otter Creeks (see Section 3.2.1), Ohio EPA personnel assigned qualitative ratings of invertebrate community quality. Fish sampling was conducted using standard electrofishing procedures. Results are summarized in Table 3-4.

As described in Section 3.1, laboratory testing demonstrated a lack of toxicity in Duck Creek sediment samples. Nevertheless, Ohio EPA rated both fish and invertebrate community quality as very poor at both 2008 sample locations. This finding may be related in part to the very small size of Duck Creek, as indicated by the small drainage area (0.6 to 0.8 mi^2 at the sampled locations). By comparison, among 30 streams assessed by Ohio EPA (2010), the smallest stream sampled outside Duck and Otter Creeks had a drainage area of 7.0 mi^2. Portions of Duck Creek can experience very low water levels during the summer, undoubtedly limiting the types of aquatic species that can persist there. As stated in Ohio EPA's recently issued *Field Evaluation Manual for Ohio's Primary Headwater Streams* (Ohio EPA 2012):

> Although many different species of fish are present in [Primary Headwater Habitat (PHWH)] streams … it becomes increasing less likely that a well-balanced fish community, as measured by the [Index of Biotic Integrity (IBI)], can be supported as watershed size falls below 1.0 mi^2 (259 ha). Limitations to the establishment of well-balanced fish communities in PHWH streams can result from the lack of suitable habitat or forage, barriers to migration (natural or artificial), or the lack of refugia [i.e., refuge areas] during low and zero flow conditions. The lack of permanent nursery areas for young-of-the year fish also may preclude the establishment of well-balanced fish communities in PHWH systems. Therefore, many fish species may be only temporally resident as they move in and out of PHWH streams to exploit seasonally available food resources.

Habitat quality in Duck Creek is also very poor. For example, Duck Creek upstream of the Consaul Avenue sampling location consists of a straightened ditch alongside the City Water

Treatment sedimentation pond, with flow made up predominantly of sedimentation pond overflow.

Consistent with the 2010 macroinvertebrate community evaluation, Ohio EPA collected fewer invertebrate taxa in Otter Creek than in Duck Creek. OEPA's 2006 invertebrate sampling effort did not include any sample locations in lower Otter Creek (downstream of Millard Avenue). Ohio EPA qualitatively rated benthic invertebrate community quality in Otter Creek as very poor. Ohio EPA's qualitative rankings are based on professional judgment, considering information such as total taxa, EPT taxa, sensitive taxa, and tolerant taxa, as well as a reliance on detailed field observations of physical habitat conditions and predominant populations residing in the various macrohabitats that are available at a sampling site (Jeff DeShon, Ohio EPA, personal communication).

Fish community quality in Otter Creek met Ohio EPA's biocriteria at the two downstream-most sample locations in Otter Creek, despite the observations of sediment toxicity in downstream portions of Otter Creek. Markedly lower Qualitative Habitat Evaluation Index (QHEI) scores at the two fish sampling locations further upstream may have contributed to lower fish community quality at these locations. Interestingly, no observations of deformities, eroded fins, lesions, or tumors (DELT anomalies) were recorded in fish from either creek; such external anomalies are considered a potential indicator of toxic effects.

Overall, Ohio EPA's 2006-2008 invertebrate community data are difficult to interpret in the context of sediment toxicity test results due to the qualitative nature of the invertebrate community sampling and the small number of locations evaluated. Quantitative fish community scores appear to be strongly influenced by physical habitat characteristics. The observation of good fish community quality in downstream portions of Otter Creek indicates that effects on fish related to benthic toxicity (if any) are limited.

3.3 Consistency with 2007 Sediment Toxicity Testing

Toxicity testing conducted in 2010-2011 found sediment toxicity in Duck and Otter Creeks to be much less widespread than was reported based on toxicity testing in 2007. Indeed, one of the objectives of the DGI was "verifying sediment toxicity" because significant concerns had been raised regarding the quality of the 2007 toxicity data. These included concerns about aeration procedures and observations of sediment avoidance behavior.[2] An important focus of the DGI was the selection of a high-quality toxicity testing laboratory. ERDC was selected because of its international reputation, track record of high control survival, and in-house culture of test organisms. Specific reasons for the lower toxicity test organism performance in 2007 are likely unknowable, but it is possible that the indigenous predatory flatworms observed by ERDC could also have been present in 2007. If predatory organisms were present in the 2007 sediment samples and were not recognized as a data quality concern by the toxicity testing laboratory, then the extent of toxicity would have been overestimated.

[2] See Duck and Otter Creeks Risk Assessment Comments Compendium (Dec 2008), at: http://www.partnersforcleanstreams.org/index.php/reports/reports-from-projects-in-the-area-of-concern

3.4 Summary

Sediment toxicity testing conducted in 2010-2011 indicated effects on midge biomass in sediment samples from downstream portions of Otter Creek. Toxicity generally was not observed in Duck Creek sediments, with the exception of a single sample collected near the creek mouth. Toxicity also was not observed in upper Otter Creek. Benthic invertebrate community characteristics are generally consistent with toxicity test results for Duck and Otter Creeks.

4 PAHs and Petroleum Hydrocarbons

The evaluation presented in the DGI report (Cardno Entrix 2012) points to PAHs as the primary cause of sediment toxicity in Otter Creek. Porewater PAH concentrations were predictive of biological effects in the 2010 sediment triad samples. However, bulk sediment total PAH concentrations were not related to toxicity test results or benthic community characteristics; indeed, the highest total PAH concentrations were reported from non-toxic samples.

The larger data set of sediment and porewater PAH and petroleum hydrocarbon results compiled for this supplemental data evaluation is reviewed below (Section 4.1), followed by a detailed evaluation of the exposure-response relationship for porewater PAHs in the combined DGI and confluence area data sets (Section 4.2). Additional lines of evidence for understanding PAH exposures include correlations between porewater PAHs and petroleum hydrocarbon concentrations (Section 4.3), qualitative field observations such as presence of sheens (Section 4.4), a fingerprinting analysis of PAH composition (Section 4.5), and biota tissue analyses (Section 4.6). Since porewater PAHs were analyzed in only a limited number of surface sediment samples, a means of extrapolating from porewater results is needed to interpret the sediment quality at other sampling locations. An evaluation of options for such extrapolation is provided in Section 4.7. This section concludes with a description of the magnitude and extent of sediment impacts due to PAHs in Duck and Otter Creeks.

4.1 Data Summary and Screening

Summary statistics for PAHs and petroleum hydrocarbons are presented in Tables 4-1 through 4-4. Concentrations are summarized separately for each creek and for surface sediments (grab samples) and core samples. Surface grab samples generally included the top 6 to 12 inches of sediment. The core sample summaries include samples representing the top two feet of sediment, as well as deeper cores. Relative to the biologically active zone (often estimated as the top 6 inches of sediment), the 0-2-foot samples represent a combination of surface and subsurface sediment. Within each table, results from the GLNPO 2007 sampling event are summarized separately from all other data. Although the difference is more pronounced for metals (see Section 5), mean PAH concentrations in the GLNPO 2007 data set are also higher than in other data sets for Duck and Otter Creeks. The maximum PAH concentrations in the GLNPO 2007 data set were reported from Hecklinger Pond, which was not resampled in the GLLA 2010-2011 sampling. This difference appears to account in large part for the difference in mean total PAH concentrations. During subsequent site visits, asphalt particles were observed to be prevalent in the portion of Hecklinger Pond where the highest PAH concentrations were reported. Additional discussion of possible causes of concentration discrepancies between the GLNPO 2007 data set and all other data are discussed in Section 5.

Concentrations of PAHs are summarized using several metrics, as follows:

- Summed concentrations of 16 Priority Pollutant PAHs are presented, with and without normalization to 1% TOC. Total PAH-16 results are compared to the Probable Effect Concentration (PEC) of 22.8 mg/kg from MacDonald et al. (2000).

- Concentrations of an extended PAH analyte list (33 to 34 PAHs) are also summed, with and without TOC normalization. These concentrations are not directly comparable to the PEC.

- Equilibrium partitioning sediment benchmark toxic units (ESBTU) were calculated according to USEPA (2003) and Burgess (2009) methods. TUs are calculated for individual PAHs as the organic carbon normalized sediment concentration divided by the corresponding benchmark concentration, and the individual PAH TUs are then summed for each sample. The ESBTU approach uses default organic carbon-water partition coefficients (K_{oc} values) to back-calculate sediment benchmarks from porewater PAH benchmarks, where a USEPA-derived PAH water quality value for each PAH defines the protective benchmark for that compound. This approach predicts that toxicity could occur at ESBTU levels exceeding 1.

- Porewater PAH TUs are calculated using the same approach described for ESBTUs, except that it is not necessary to estimate the bulk sediment concentration associated with each porewater toxicity threshold. Extensive research has demonstrated that direct measurement of PAHs in porewater provides much more reliable toxicity predictions than any of the other PAH metrics described above (McDonough et al. 2010).

The spatial distributions of total PAH-16 concentrations, ESBTUs, and porewater PAH TUs are shown in Figures 4-1 through 4-3. Total PAH-16 concentrations and ESBTU values tend to be elevated in the upstream reaches of Duck and Otter Creeks where sediment toxicity was not observed. Conversely, porewater PAH TUs are elevated in lower Otter Creek, corresponding to observed toxicity test results.

4.2 Concentration-Response Relationship for Porewater PAHs

As illustrated in Figure 4-4, porewater PAH TUs and midge biomass results show a clear concentration-response relationship, which is not observed for other measures of PAH exposure (total PAH-16, total PAH-34, ESBTU). Additional graphical comparisons of PAH and petroleum hydrocarbon exposure measures and midge biomass are presented in Attachment 2.

To quantify the concentration-response relationship for porewater PAH TUs, logistic curve fitting was applied to the porewater toxic units and biomass results using the following equation:

$$Biomass = \frac{asy}{1+e^{xmid-\frac{\log TU}{scal}}} \qquad \text{Eqn. 1}$$

Where:

Biomass = midge biomass (fraction of control)
TU = porewater PAH toxic unit
asy = upper asymptote parameter = 0.8925
xmid = inflection point = 2.310158
scal = scaling coefficient = -0.4863773

The coefficients asy, xmid, and scal were determined iteratively using R statistical software. Curve fit results are shown in Figure 4-5.

A site-specific toxicity threshold for midge biomass effects was identified from the curve fit results. The theoretical toxicity threshold for porewater PAH TU is 1; this toxicity threshold is designed to provide a level of protection comparable to USEPA water quality criteria (WQC). Standard toxicity tests yield somewhat higher thresholds. For example, extensive testing with the amphipod *Hyalella azteca* supports a threshold for porewater PAHs of approximately 5 to 10 TU for effects on 28-day survival (Geiger 2010). For Duck and Otter Creeks, a toxicity threshold was identified as the porewater PAH TU level corresponding to a 20% reduction in midge biomass, calculated in comparison to the upper asymptote of the fitted curve (i.e., the typical midge biomass result for Duck and Otter Creek sediments in the absence of elevated porewater PAH exposure). On this basis, the site-specific toxicity threshold for effects on midge biomass is a porewater PAH TU value of 5.

Additionally, a site-specific threshold was identified for severe toxic effects. Specifically, a porewater PAH TU value of 10 corresponds to a 50% reduction in midge biomass relative to the upper asymptote of the fitted curve. This value is intended to facilitate understanding of the magnitude of predicted toxicity in lower Otter Creek sediments.

Comparisons of porewater PAH TU results with the identified site-specific thresholds are shown geospatially in Figure 4-3. Additional discussion of the extent of potential toxicity is presented in Section 4.7.

4.3 Petroleum Hydrocarbons

Scatter plots were prepared to compare porewater PAH TUs to bulk sediment parameters, as shown in Attachment 3; examples are shown in Figure 4-6. Diesel range organics (DRO) concentrations show the best correlation with porewater PAH TUs, better than measures of bulk sediment PAH concentrations. This relationship might possibly be due to a solvent effect of hydrocarbons whereby PAHs sorb less strongly to sediment organic carbon in the presence of petroleum hydrocarbons.

The relationship between DRO and porewater PAH TUs was quantified using a hockey-stick regression, as shown in Figure 4-7. This type of regression is used to account for threshold-dependent relationships. In this case, there is no correlation between porewater PAH TUs and DRO at lower concentrations, but the two parameters are closely correlated at higher concentrations (r^2=0.84, p <0.0001). This regression analysis allowed the calculation of DRO concentrations corresponding to the porewater PAH TU benchmarks identified in Section 4.2, which facilitates interpretation of the spatial distribution of DRO concentrations (see Figure 4-8).

4.4 Field Observations

Observations of sheen associated with sediment sampling, odors, and visible oil were extracted from Weston's field notes for the GLLA 2010-2011 sampling events. These observations are inherently subjective, especially observations of odor. Both odor and sheen can originate from sources other than petroleum, although they are also associated with petroleum-contaminated sediments. Field observation results are presented in Table 4-5 and are mapped in Figure 4-9. Observations of sheen tend to correspond with areas of elevated porewater PAHs and DRO. "Visible oil" was restricted to a small area near the end of the jetty that extends into the Otter

Creek confluence area; however, the specific difference between “visible oil” and “sheen” is uncertain.

4.5 PAH Mixture Composition (Fingerprinting)

A chemical fingerprinting analysis of sediment PAH composition in Duck and Otter Creeks surface sediment is described in Attachment 4. This analysis was conducted using the GLNPO 2007 and GLLA 2010-2011 data sets, including surface sediment samples analyzed for parent and alkylated PAHs. The fingerprinting analysis identified four types of PAH mixtures corresponding to the following categories:

1. Petroleum-derived PAHs
2. Weathered petroleum-derived PAHs
3. Mixed urban background and petroleum-derived PAHs
4. Urban background PAHs, primarily from combustion-related sources

The spatial distribution of these PAH categories is shown in Figure 4-10. In general, the first two types of PAH mixtures are associated with areas of elevated porewater PAHs. However, PAH mixture composition is independent of PAH concentrations, and it does not account for potential effects of DRO on PAH bioavailability. Thus, PAHs in the Duck Creek confluence area correspond to weathered petroleum-derived PAHs but are associated with lower porewater PAH concentrations. Finally, PAHs originating from urban background sources tend to be less bioavailable than petroleum-related PAHs in Duck and Otter Creeks, since elevated total PAH concentrations are found in the upper reaches of the creeks in the absence of elevated porewater PAHs.

4.6 Tissue Analyses

Benthic macroinvertebrate tissue samples were analyzed for PAHs as part of the DGI effort, while USFWS analyzed PAHs in fish tissue samples. Additionally, the Duck and Otter Creek Industrial Partners analyzed a small number of split samples of fish tissue concurrently with the USFWS analyses.

As part of the DGI report (Cardno ENTRIX 2012), PAH concentrations in benthic macroinvertebrate tissue were compared to a lipid-normalized tissue residue benchmark (2.24 micromoles per gram [µmol/g] lipid) from USEPA (2003). The benchmark was not exceeded in tissue samples from Duck and Otter Creeks and the reference site in Grassy Creek but was exceeded in the tissue sample from the reference site in Amlosch Ditch. A consistent relationship was not observed between sediment, porewater, and invertebrate PAH concentrations (Figure 4-11). Possible explanations for the lack of agreement between invertebrate tissue PAH concentrations and other site-specific lines of evidence include (1) stimulation of PAH metabolism due to higher PAH exposures in lower Otter Creek, and (2) presence of PAHs on undigested material in the gut of organisms collected from Amlosch Ditch.

Fish tissue samples were collected in six fish sampling zones within Duck Creek (zones A, D, and E) and Otter Creek (zones A, C, and D). Identifying information for each sample (e.g., fish species and size) is provided in Table 4-6. Because the USFWS data have not yet been

received in database format, one PAH analyte was selected for evaluation in this appendix. Specifically, C3-naphthalenes were selected because this homologue group was the PAH analyte with the highest concentrations in split samples (Cardno Entrix 2012). Figure 4-12 illustrates the concentrations in C3-naphthalenes in fish tissue, bulk sediment, and porewater. The highest C3-napthalene concentration occurred in a composite log perch sample in Otter Creek A (0.0694 mg/kg wet weight). Overall, higher concentrations of C3-napthalene were observed in lower Otter Creek (Otter Creek A) when compared to the other fish zones, consistent with other lines of evidence indicating higher PAH bioavailability in lower Otter Creek. However, fish tissue PAH concentrations were low overall compared to toxicological benchmarks. As determined in the DGI report for split samples of fish tissue, cumulative concentrations of all PAHs in fish tissue were well below the toxicity reference value identified from USEPA (2003). Low fish tissue C3-napthalene concentrations across all fish zones may be explained by PAH metabolism in fish.

4.7 Horizontal and Vertical Extent of Impacted Sediment

In this section, multiple lines of evidence are integrated to identify the horizontal and vertical extent of PAH-impacted sediments and resulting sediment management areas. The available lines of evidence are discussed below for the Otter Creek confluence area, lower Otter Creek (downstream of Millard Avenue), Otter Creek upstream of Millard Avenue, and Duck Creek.

Otter Creek Confluence Area. Key lines of evidence for PAHs in the Otter Creek confluence area are mapped in Figure 4-13 and are discussed below. In this figure, potentially impacted areas based on each line of evidence are shown; outlines were derived using Thiessen polygons. Data for PAHs and related lines of evidence are tabulated for the confluence area, as well as lower portions of Otter Creek, in Table 4-7.

- Toxicity test and porewater PAH results provide a generally consistent indication of the horizontal extent of impacted sediments, which occur in the center of the area sampled (Figure 4-13). For the purposes of this figure, sediment samples are considered toxic if midge biomass was significantly different than and less than 75% of the control sample.[3] Porewater PAHs are considered impacted if the TU value exceeds the site-specific threshold of 5.

- On the western edge of the confluence area, moderate toxicity (midge biomass of 68 to 69% of control) was observed at locations OC-38 and OC-46 but was not due to PAHs, based on porewater PAH TU values less than 1. No field observations of sheen, odor, or visible oil were reported for these two sample locations (Table 4-5). Based on the limited magnitude of toxicity and the lack of relationship to PAHs (or other parameters; see subsequent sections of this appendix), these locations are not included in the proposed sediment management area.

[3] A biomass threshold of 75% is based in part on the findings of Sibley et al. (1997), who demonstrated that effects on *Chironomus dilutus* reproduction were observed only when larval growth was reduced by more than 25%. The derivation of the site-specific porewater PAH TU benchmark is based on a similar reduction in midge biomass. Specifically, the porewater PAH benchmark represents a 20% reduction in biomass relative to a site-specific "baseline" biomass (equal to 89% of control); this equates to a site-specific biomass benchmark of 71% of control.

- To the east of the confluence area (locations OC-56, OC-57, and OC-60), porewater PAH TU values exceeded 5, but sediments were not toxic. Visible oil was observed in subsurface sediment from locations OC-56 (depth = 6-48 inches) and OC-57 (depth = 6-112 inches), and sheen was reported from location OC-60 (Table 4-5). These locations could potentially be affected by the immediately adjacent boat slip, where sediment quality has not been characterized, or other sources. Indeed, the chemical fingerprinting results show three different fingerprints for the three sample locations. The lack of toxicity in locations to the east of the outfall pipe indicates that sediments in this area do not pose an imminent threat of environmental harm. In addition, any intrusive remedy would need to avoid the area of the outfall pipe to avoid damaging it. The BP-Husky outfall, located just west of OC-56, thus provides a reasonable definition of the eastern edge of the Otter Creek confluence area, with locations to the east of the outfall pipe being more appropriately considered in the wider context of Maumee Bay. For these reasons, the BP-Husky outfall pipe is identified as the eastern limit of sediment management for this project.

- Figure 4-13 also shows sediment total PAH-16 concentrations compared to the PEC (22.8 mg/kg) and ESBTU values compared to the screening value of 1. These comparisons are shown for reference purposes and are not generally predictive of site-specific bioavailability or biological effects throughout the study area. The horizontal extent of potentially impacted sediments based on these comparisons is smaller than that based on porewater PAH and toxicity test results.

- To evaluate the vertical extent of potential impacts, DRO concentrations provide the most useful site-specific indicator parameter, even though DRO was not measured in all confluence area sediment cores. As described in Section 4.3, DRO concentrations and porewater PAH TU values are strongly correlated in the study area, with the site-specific porewater PAH TU threshold of 5 corresponding to 3100 mg/kg DRO. While other parameters that were measured in core samples from the confluence area do not correlate as well with porewater PAH or toxicity test results, the combination of DRO and total PAH-16 concentrations are considered as supplemental lines of evidence. At locations where DRO was measured within the confluence sediment management area, concentrations greater than 3100 mg/kg were limited to the top 24 inches of sediment or shallower (Figure 4-14). At most locations in the confluence area, total PAH-16 concentrations were also higher in the 0-24 inch depth interval than in deeper sediments. The exception is location OC-54, where total PAH-16 concentrations exceeded the PEC in the 24-48 inch and 48-65 inch depth intervals - samples where DRO was not measured.

In summary, sediment management is recommended for the area defined in Figure 4-13 for the Otter Creek confluence area. The depth of contamination is generally 2 feet or less, with the exception of location OC-54.

Lower Otter Creek Downstream of Millard Avenue. Lines of evidence to define the need for sediment management in lower Otter Creek are shown in Figure 4-15 and discussed below.

- Toxicity test and porewater PAH results are generally consistent in indicating sediment impacts in lower Otter Creek, with the exception of location OC-6/7(2) (at the upstream end of this creek segment), where neither line of evidence indicates impacts. Toxicity was also minimal at location OC-45 (biomass = 77% of control), although the porewater PAH TU value at OC-45 exceeded the site-specific threshold of 5.

- Because porewater PAH analyses and toxicity testing were conducted for only a limited subset of lower Otter Creek sample locations, DRO is also considered in identifying the horizontal extent of sediment impacts (Figure 4-15). Both surface grab samples and 0-24 foot core samples are considered. DRO results for the 0-24 inch interval indicate impacts at all locations in lower Otter Creek except OC-6/7(2). At several locations, the surface sediment (0-6 inch) DRO concentrations were below 3100 mg/kg, but these locations are interspersed among locations where the 0-6 inch DRO concentration exceeded 3100 mg/kg. Also, at location OC-5A, the porewater PAH TU value exceeds the site-specific threshold of 5, even though the 0-6 inch DRO concentration was below 3100 mg/kg. The DRO results are thus interpreted to indicate sediment impacts throughout the lower Otter Creek segment, downstream of location OC-6/7(2).

- Similar to the confluence area, comparisons of sediment total PAH-16 concentrations and ESBTU values to screening values would predict a smaller extent of sediment impacts than the lines of evidence described above (Figure 4-15). Both parameters exceed the respective screening values at location OC-3 and in a small area near the mouth of the creek. Additionally, an ESBTU result slightly exceeding 1 indicates a potential impact immediately downstream of Millard Avenue (sample location SITE 1); however, this result may be biased high due to our use of a conservative default TOC concentration in the ESBTU derivation (see Table 4-7).

- Sheen was reported at several sample locations in lower Otter Creek (including location OC-6/7(2)).

- In addition to the lack of porewater and toxicity impacts at location OC-6/7(2), numerous pipelines cross Otter Creek in the area immediately downstream of Millard Avenue, greatly constraining sediment management options in this area. Based on these factors, the area immediately downstream of Millard Avenue is not included in the sediment management area shown in Figure 4-15.

- With respect to vertical extent of contamination, DRO results for lower Otter Creek generally indicate potential impacts throughout the depth of sediment sampled, 48 inches in most cases (Figure 4-16). Total PAH-16 concentrations also do not decrease with depth at most locations. At location OC-3, DRO was below 3100 mg/kg in the 24-48 inch depth interval, but DRO concentrations above 3100 mg/kg were reported from the 24-48 inch interval at locations both upstream and downstream of this point. Only the sediment core from location OC-2A extended deeper than 48 inches; the 48-72 inch sample contained DRO at a concentration below 3100 mg/kg. The depth of sediment is

less than four feet near the creek mouth, with refusal encountered at 25 to 27 inches at locations OC-44 and OC-45.

Based on the lines of evidence presented above, sediment management is recommended to a depth of four feet (or the depth of sediment, if less than four feet) in lower Otter Creek downstream of sample location OC-6/7(2).

Otter Creek Upstream of Millard Avenue. Sediment management is not recommended for PAHs in Otter Creek upstream of Millard Avenue, for reasons discussed below.

- No porewater PAH TU values exceeding the site-specific threshold of 5 were observed in Otter Creek upstream of Millard Avenue. Consistent with this result, toxicity also was not observed, except at location OC-9/10 (biomass = 49% of control). Benthic invertebrate community quality rankings were consistently better in Otter Creek upstream of Millard Avenue than downstream of this point (see Section 3.2).

- Because porewater PAH analyses and toxicity testing were conducted for only a limited subset of sample locations, DRO is also considered as a line of evidence in identifying the horizontal extent of sediment impacts (see Figure 4-8). DRO concentrations indicative of potentially elevated porewater PAH concentrations are limited to the vicinity of Westover Landfill (locations OC-8 and OC-8/9) and an isolated location upstream of Consaul Street (location OC-11/12). Note that multiple pipelines traverse the area near Westover Landfill, which would limit sediment management options in this area.

- The field observations (Figure 4-9) and fingerprinting results (Figure 4-10) are generally consistent with the DRO results. Upstream of Millard Avenue, sheen was observed only at location OC-11/12 and two locations in the Otter Creek headwaters. A petrogenic fingerprint was observed only at location OC-11/12, and a weathered petrogenic fingerprint was observed only at two locations near the Westover and Envirosafe landfills.

- In contrast to lower Otter Creek and the confluence area, comparison of bulk sediment PAH concentrations to the PEC of 22.8 mg/kg or bulk sediment ESBTU values to the screening value of 1 would predict sediment impacts at several locations in upper Otter Creek (Figure 4-1). However, all other lines of evidence indicate that aside from the specific locations noted above, PAHs are not bioavailable or toxic in upper Otter Creek. This conclusion is consistent with the urban comparison stream results, which included a sample with notably elevated total PAH-16 concentrations that was not toxic.

In summary, sediments are not adversely impacted by PAHs in most of Otter Creek upstream of Millard Avenue. Although DRO results suggest possible impacts in a few areas between Millard Avenue and OC-11/12, these results are uncertain in the absence of porewater PAH data and represent only a limited spatial extent.

Duck Creek. Sediment management is not recommended for PAHs in Duck Creek or the Duck Creek confluence area for the reasons discussed below.

- Porewater PAH TU values did not exceed the site-specific threshold of 5 at any sediment sample locations in Duck Creek (Figure 4-3).

- Toxicity was observed only at location DC-25 and was moderate (biomass = 69% of control). This was also the only location where sheen was observed in Duck Creek. This location represents a sufficiently small area and limited magnitude of effect that sediment management is not warranted.

- Benthic invertebrate community characteristics in Duck Creek were similar to those at two urban reference stream locations, as well as the upstream-most location in Otter Creek (Section 3.2).

- Because porewater PAH analyses and toxicity testing were conducted for only a limited subset of sample locations, DRO is also considered in identifying the horizontal extent of sediment impacts. There are no DRO results indicative of potential impacts from any surface sediment sample in Duck Creek or the Duck Creek confluence area (Figure 4-8).

- As in upper Otter Creek, comparison of bulk sediment PAH concentrations to the PEC of 22.8 mg/kg would predict sediment impacts at several locations in upper Duck Creek, but other lines of evidence indicate a lack of adverse impacts. Particularly elevated PAH concentrations were reported for Hecklinger Pond (location DC-14), but these results might have been associated with asphalt particles, which are prevalent in the area. Even though the 2007 toxicity test results generally were found to overestimate sediment toxicity (see Section 3), elevated PAH concentrations in Hecklinger Pond sediments were associated with a lack of toxicity in 2007 tests (SulTRAC 2007).

- With respect to subsurface sediments, only two locations exhibited DRO concentrations exceeding 3100 mg/kg at depth (locations DC-2 and DC-5). The sediments containing these elevated DRO concentrations are present beneath at least 2 feet of clean sediment. The observed vertical stratification of DRO concentrations indicates that sediments at these locations have been physically stable for many years.

In summary, PAHs in surface sediments of Duck Creek and the Duck Creek confluence area are not bioavailable at levels of concern. Indications of potential sediment impacts are limited in spatial extent and are also either of limited magnitude (DC-25) or are limited to buried sediments (DC-2 and DC-5). Therefore, sediment management is not needed for PAHs in Duck Creek.

5 Metals

Metals have been measured in Duck and Otter Creek sediment, porewater, and invertebrate and fish tissue. Metals data are available for sediment samples collected between 2006 and 2011. Tissue samples were collected in 2010, and porewater samples were collected in 2010 and 2011. This section evaluates the potential contribution of metal concentrations in Duck and Otter Creek sediment to sediment toxicity.

5.1 Sediment Data Summary

Summary statistics of metal concentrations in surface sediment and sediment cores are provided in Tables 5-1 through 5-4. Metal concentrations reported for GLNPO 2007 sediment samples were systematically higher than in samples from all other sediment sampling events. The difference between the GLNPO 2007 concentrations and all other sediment data is evident in Figures 5-1 through 5-5. Possible explanations for the observed discrepancy are discussed below, focusing specifically on the GLNPO 2007 and GLLA 2010-2011 sediment sampling results.

Table 5-5 compares aspects of the study methodologies between the GLNPO 2007 and GLLA sediment investigations. The most notable difference is that the GLNPO 2007 surface grab sampling targeted a greater sediment depth (top 6 to 12 inches) compared to the GLLA sampling (top 3 to 6 inches for surface grabs). However, the sediment core sampling results indicate that GLLA subsurface metal concentrations are no more comparable to the GLNPO 2007 data than are the GLLA surface sediment concentrations. Differences between laboratories are a likely explanation of the observed systematic differences, as small differences in extraction methods, even within the constraints of standard USEPA protocols, can affect extraction efficiency.

Some stakeholders have speculated that metals concentrations in 2010-2011 may have been lower than in 2007 because large amounts of sediment were transported downstream during extreme weather that occurred between the two sampling events. If this were the case, one would expect that elevated concentrations would still be present in the creeks or confluence areas in 2010-2011, but would be observed further downstream than in 2007. However, this trend is not observed in Figures 5-1 through 5-5. These results suggest that sediment transport is not the best explanation for discrepancies between the GLNPO 2007 and GLLA data sets.

Despite limitations on the comparability of total metal concentrations between the GLNPO 2007 data and other data sets, there is ample evidence from multiple data sets (including GLNPO 2007) indicating that metals in Duck and Otter Creeks are neither bioavailable nor toxic (see Section 5.3).

5.2 Screening Evaluation

Arsenic, chromium, and lead are the primary metals of interest in Duck and Otter Creeks sediment based on the screening evaluation described below. Consistent with the screening approach used in the DGI report, the initial step in this evaluation of metals in Duck and Otter Creeks is the comparison of metal concentrations to PEC screening benchmarks from MacDonald et al. (2000) (Tables 5-1 through 5-4). As shown in Table 5-6, there is generally a

higher frequency of exceedances observed in surface sediment as opposed to core sediment samples, with the exception of chromium in Otter Creek sediment cores. Higher exceedance frequencies than observed in the DGI report are generally due to the inclusion of GLNPO 2007 data in the screening.

Toxicity-based sediment screening values are not available for several metals. Conclusions regarding the potential for these metals to contribute to sediment toxicity follow:

- Macronutrients (calcium, magnesium, potassium, and sodium) play critical roles in biological function, as shown by the adverse health outcomes associated with short-term deprivation of these elements. Iron is an essential micronutrient, and is not considered a significant bioaccumulative chemical. Quantitative toxicity screening levels have not been established for these essential nutrients because they are naturally occurring and are generally non-toxic.

- Information on cause-effect, concentration-response relationships for effects on benthic invertebrates is generally lacking for several metals (i.e., aluminum, antimony, barium, beryllium, cobalt, manganese, strontium, thallium, and vanadium). None of these metals are listed as persistent, bioaccumulative, and toxic pollutants (PBTs) under the Toxics Release Inventory (TRI) Program[4]. Further, as discussed in Section 5.3.1, concentrations of these metals generally do not show a concentration-response relationship to measured site-specific toxicity.

- Selenium is a bioaccumulative metal that can biomagnify if it is significantly bioavailable in sediments. Low concentrations in fish tissue indicate that sediment concentrations are not of concern. As described in Section 5.3.4.2, the selenium concentrations in Duck and Otter Creeks fish tissue are below levels of concern.

- The bioavailability of silver is evaluated using measures of AVS and SEM as discussed in Section 5.3.2; based on the SEM-AVS analysis, silver is unlikely to contribute to observed benthic invertebrate toxicity.

A summary of observed exceedances of metal concentrations in sediment for which PECs are available (i.e., arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) is shown in Table 5-6. The magnitude of arsenic, chromium, and lead exceedances warrants a focused evaluation of the potential for these metals to contribute to sediment toxicity. The discussion of metal bioavailability in Section 5.3 focuses primarily on arsenic, chromium, and lead. It is evident from Figures 5-1 and 5-4 that the majority of arsenic and lead exceedances are from the GLNPO 2007 data set. Chromium exceedances are widespread in Otter Creek, particularly the lower reach (Figure 5-2). Copper and nickel are mapped in Figures 5-3 and 5-5; these metals were not measured in the GLNPO 2007 investigation. Exceedances of copper and nickel are of limited extent and do not appear to be localized in any “hot spot” areas. While zinc exceeds the PEC in both Otter Creek and Duck Creek surface sediment, all but one of the exceedances are from the systematically higher concentrations in the GLNPO 2007 data set. Cadmium and

[4] http://www.epa.gov/tri/trichemicals/pbt%20chemicals/pbt_chem_list.htm

mercury exceed the PEC at a frequency of less than 10% of samples in either Duck or Otter Creek.

5.3 Site-Specific Evidence of (Low) Bioavailability

Several site-specific lines of evidence indicate low metal bioavailability, including (1) the absence of site-specific concentration-toxicity relationships for total metals in sediment, (2) SEM-AVS analyses, (3) porewater analyses, and (4) biota tissue analyses.

5.3.1 Total Metals versus Toxicity

To evaluate whether the 2010-2011 sediment toxicity test results displayed a dose-dependent relationship with sediment concentrations, bulk sediment metal concentrations were plotted against biomass results. The complete set of scatter plots is provided in Attachment 2. Figure 5-6 demonstrates the absence of a dose-dependent relationship between bulk sediment concentrations of arsenic, chromium, and lead, and invertebrate toxicity; the same trend is observed for all other metals (Attachment 2). In general, bulk sediment concentrations are not the most accurate predictor of toxicity. Even the bulk sediment concentrations of PAHs fail to display a dose-dependent relationship with biomass, despite the fact that PAHs in porewater appear to explain observed toxicity test results. Therefore, SEM-AVS and porewater analyses were conducted, which are generally considered to more accurately predict toxicity than bulk sediment chemistry, as discussed below.

5.3.2 SEM-AVS

The bioavailability of divalent metals (cadmium, copper, lead, nickel, silver, zinc) in Duck and Otter Creeks was assessed in 2007, 2010, and 2011 using analyses of AVS and SEM. Sulfide is a key factor controlling the bioavailability of divalent metals. AVS is a measure of the excess sulfide available to form insoluble salts with simultaneously extracted divalent metal ions; divalent metals are not bioavailable in this form. Thus, if the concentration of AVS is greater than the concentration of SEM in sediment on a molar basis, the metals are not bioavailable and do not cause toxicity (Ankley et al. 1996, USEPA 2005). The measure of divalent metal bioavailability is further refined by normalizing the measure of excess SEM to TOC in sediment (USEPA 2005). This approach can predict with 90% confidence that sediment toxicity will not occur if the organic-carbon normalized concentration of “excess” metals ([ΣSEM-AVS] / fraction organic carbon [f_{OC}]) is less than 130 micromoles per gram organic carbon (µmol/gOC) (USEPA 2005).

As shown in Figure 5-7, all sediment locations where AVS was measured contained sufficient sulfide and organic carbon to bind the SEM. For most sediment samples, the AVS content was much greater than the cumulative SEM concentration, and the SEM-AVS/foc values are negative numbers (Table 5-7). The results from the GLNPO 2007 data set are consistent with the 2010-2011 data set in indicating that cadmium, copper, lead, nickel, silver, and zinc are not bioavailable in the sediments of Duck and Otter Creeks.

The AVS data also indicate that chromium bioavailability is minimal throughout both creeks. Chromium exists in two forms: hexavalent chromium is more soluble and toxic than trivalent chromium, and is rapidly reduced to trivalent chromium under even moderately reducing conditions. AVS is formed in anoxic sediments under reducing conditions, the same conditions

under which hexavalent chromium is reduced to the trivalent state (Berry et al. 2004, Besser et al. 2004, Becker et al. 2006). As described by USEPA (2005), where AVS is detectable, chromium is present in the minimally toxic trivalent form. AVS was detected at all but two of the sediment locations where it was measured, indicating that chromium is not expected to be bioavailable at most locations. Porewater analyses provide additional evidence of low chromium bioavailability (Section 5.3.3).

5.3.3 Porewater Metals

Porewater analyses conducted in 2010 and 2011 were used to evaluate bioavailability of target metals in Duck and Otter Creeks. Porewater metals were analyzed for samples from the same locations as porewater PAHs (see Figure 4-3). Whereas SEM-AVS results are only applicable to selected metals, porewater concentrations can be interpreted for all analyzed metals. For this evaluation, porewater is assumed to be the critical exposure pathway for benthic invertebrates with toxicity thresholds comparable to surface water (USEPA 2005). The porewater data are screened against Ohio EPA (2009) Lake Erie Basin Aquatic Life outside mixing zone average (OMZA) WQC in Table 5-8. The Michigan Department of Environmental Quality (MDEQ) has developed final chronic values (FCV) (analogous to OEPA's OMZA) using Great Lakes Initiative methodology. Where OEPA WQC are not available, Michigan FCV are used. Hardness-dependent WQC are calculated with the average porewater hardness measured in Duck and Otter Creeks (400 milligrams per liter [mg/L] as $CaCO_3$).

Maximum arsenic and lead concentrations in porewater are 2- to 3-fold less than their respective WQC, while the maximum chromium concentration in porewater is more than an order of magnitude below its WQC. All other metal concentrations are below the WQC, with the exception of barium. Barium exceeds the OEPA WQC (220 micrograms per liter [µg/L]) at two locations, DC-11/12 and DC-20. However, barium concentrations in porewater do not exceed the MDEQ hardness-dependent FCV for barium (1911 µg/L).

Further, in most cases, there is no apparent relationship between porewater metal concentrations and toxicity test results, as shown in Attachment 2. The exception is porewater lead, which does show a correlation with midge biomass. Bioavailable lead appears to be co-located with concentrations of bioavailable PAHs. However, PAH concentrations are above the expected toxicity threshold, while lead concentrations are below the WQC. Thus, the role of lead (if any) in contributing to sediment toxicity in lower Otter Creek and the confluence area is expected to be limited to that of a secondary stressor.

5.3.4 Tissue Analyses

Tissue residue-effect relationships for metals generally are not well understood for aquatic species, and tissue-based toxicity thresholds are not available for most metals, including arsenic, chromium, and lead (Adams et al. 2011). However, an evaluation of spatial trends in sediment, porewater, and biota tissue concentrations indicates little correlation among media for arsenic, chromium, and lead in Duck and Otter Creeks, implying low bioavailability.

5.3.4.1 Invertebrate Tissue

Invertebrate tissue was collected at two locations in Duck Creek, three locations in Otter Creek, and at one location each in Grassy Creek and Amlosch Ditch. Arsenic concentrations in

invertebrate tissue collected at DC-11/12 and DC-5 appear to be related to sediment and porewater concentrations at these locations. However, no consistent concentration-dependent relationship exists for arsenic at the other six locations shown in Figure 5-8. Chromium concentrations in invertebrate tissue show low variability and no relationship to sediment and porewater concentrations (Figure 5-9), indicating low bioavailability. In Figure 5-10, lead concentrations are variable in invertebrate tissue, but also lack a dose-dependent relationship between exposure concentrations in sediment and porewater and uptake of lead into invertebrate tissue.

5.3.4.2 Fish Tissue

Fish tissue samples were collected in six zones within Duck and Otter Creeks; additional details are provided in Section 4.6. Maximum arsenic and lead concentrations were measured in common carp collected from Otter Creek zone A. White sucker collected from the same zone contained the maximum chromium concentration. As shown in Figures 5-11 through 5-13, average arsenic, chromium, and lead concentrations in fish tissue display low variability between fish zones despite clear trends in average sediment concentrations in the fish zones. The absence of a concentration-dependent relationship is indicative of low bioavailability, and, potentially, metabolic regulation of these metals in fish.

The USFWS fish tissue data were also briefly reviewed for two bioaccumulative metals, mercury and selenium. Because these metals can biomagnify if they are significantly bioavailable in sediments, low concentrations in fish tissue help confirm that sediment concentrations are not of concern. The maximum mercury concentration in Duck and Otter Creeks fish was 0.15 milligrams per kilogram (mg/kg) wet weight. By comparison, Beckvar et al. (2009) identified a screening value for mercury of 0.2 mg/kg for protection of fish; Evers et al. (2011) identified a screening value of 0.16 mg/kg for protection of fish-eating wildlife; and USEPA (2001) has established a human health criterion for mercury in fish of 0.3 mg/kg. The maximum selenium concentration in Duck and Otter Creeks fish was 7.2 mg/kg dry weight. By comparison, USEPA (2004) has identified a selenium criterion of 7.91 mg/kg dry weight in fish tissue for protection of fish health. Thus, the mercury and selenium concentrations in Duck and Otter Creeks fish tissue are below levels of concern.

5.4 Supplemental Lines of Evidence from Scientific Literature

As described above, several lines of evidence indicate low metal bioavailability, despite the fact that metals are present in sediment at concentrations exceeding PEC screening values. The PECs are based on associations between chemical concentrations and toxicity, but they do not necessarily reflect cause-effect, concentration-response relationships, and they do not account for chemical bioavailability (Wenning et al. 2005, Batley et al. 2005). As supplemental lines of evidence for arsenic, chromium, and lead, spiked sediment toxicity tests and toxicity or benthic data from sediment sites contaminated primarily by one or a few metals are reviewed. The total metal exposures in such studies provide insight into the ranges of concentrations that may cause toxicity in sediment environments.

5.4.1 Arsenic

Four spiked sediment toxicity studies for arsenic were identified; they provide data for several benthic invertebrate species, forms of arsenic, and types of sediment (Table 5-9). The reported

toxicity values from these studies are above 100 mg/kg dry weight in all cases. In general, spiked sediment studies are more likely to overestimate rather than underestimate bioavailability of metals relative to field-contaminated sediment. Slow sorption and mineralization processes tend to progressively decrease metal bioavailability in sediments, but in spiked sediment tests, the time elapsed between sediment spiking and exposure of organisms often is not sufficient for these processes to approach field conditions.

Table 5-10 presents sediment toxicity and/or benthic invertebrate community data for three sites where the study authors considered arsenic the primary contaminant of concern. At two of the sites, no adverse effects on invertebrates were observed at the maximum arsenic concentrations evaluated (approximately 180 to 340 mg/kg). At the third site, where antimony was a co-contaminant, the threshold for adverse effects on the benthic invertebrate community was between 100 and 200 mg/kg arsenic. The difference between the arsenic toxicity thresholds of greater than 100 mg/kg derived from the studies described here and the arsenic PEC of 33 mg/kg shows that while the PEC may often be associated with an increase in toxicity due to exposure to multiple chemicals, including arsenic, it is not necessarily predictive of toxicity due specifically to arsenic.

5.4.2 Chromium

A total of nine spiked sediment toxicity studies for chromium were identified from two publications (Table 5-11). In sediments spiked with trivalent chromium at concentrations well over 1,000 mg/kg, only minimal effects were observed. In hexavalent chromium-spiked sediments, toxicity was also associated with concentrations exceeding 1,000 mg/kg, except in cases where AVS was absent. Table 5-12 presents sediment toxicity data for three sites where the study authors considered chromium the primary contaminant of concern. As in the spiked sediment studies, toxicity thresholds for chromium substantially exceeded 1,000 mg/kg. These findings indicate that the chromium PEC of 111 mg/kg is not predictive of toxicity due specifically to chromium.

5.4.3 Lead

The site-specific toxicity of lead in sediment depends on a variety of factors, such as the concentrations of sulfide, TOC, pH, and other divalent metals. For this reason, spiked sediment toxicity tests and tests of field-contaminated sediments representing a range of species and sediment types have yielded a wide range of toxicity thresholds for lead. The results of nine lead-spiked sediment toxicity studies are summarized in Table 5-13. Reproductive effects were observed at the spiked sediment concentration of 234 mg/kg lead, but control performance was poor in this study (Ringenary et al. 2007). In other spiked sediment tests, effects were observed only at lead concentrations exceeding 500 mg/kg. Toxicity thresholds for lead from three representative lead-contaminated sediment sites are presented in Table 5-14. The lead concentrations in these field sediments associated with adverse effects were also greater than 500 mg/kg. As observed for arsenic and chromium, the PEC for lead (128 mg/kg) may often be associated with an increase in toxicity due to exposure to contamination by multiple chemicals, including lead, but is not predictive of toxicity due specifically to lead.

5.5 Summary

Arsenic, chromium, and lead have the most widespread PEC exceedances in sediment, with the majority of arsenic and lead exceedances from the GLNPO 2007 data set. Chromium exceedances are widespread in Otter Creek sediment, particularly the lower reach. Several other metals exceeded the PEC to a more limited extent. Although total metal concentrations reported for GLNPO 2007 sediment samples were systematically higher than in all other sediment samples, there is ample evidence from multiple data sets (including GLNPO 2007) indicating that metals in Duck and Otter Creeks are neither bioavailable nor toxic. Lines of evidence are summarized below.

- No concentration-dependent relationship is observed between bulk sediment concentrations of arsenic, chromium, and lead and the 2010-2011 sediment toxicity test biomass results; the same trend is observed for all other metals (Attachment 2).
- All sediment locations where AVS was measured contained sufficient sulfide and organic carbon to bind the SEM. The results from the GLNPO 2007 data set are consistent with the 2010-2011 data set in indicating that cadmium, copper, lead, nickel, silver, and zinc are not bioavailable in the sediments of Duck and Otter Creeks.
- As described by USEPA (2005), where AVS is detectable, chromium is present in the minimally toxic trivalent form. AVS was detected at all but two of the sediment locations where it was measured, indicating that chromium is not likely to contribute to sediment toxicity.
- Porewater concentrations for all analyzed metals are below surface water concentrations associated with adverse biological effects. Additionally, porewater metal concentrations generally show little if any relationship to toxicity test results. Concentrations of lead in porewater are associated with reduced midge biomass; this finding may be attributed to (1) co-variance between porewater lead and toxic levels of porewater PAHs, and/or (2) lead acting as a secondary stressor in some sediment samples.
- No concentration-dependent relationship exists between exposure concentrations in sediment and porewater and uptake of arsenic, chromium, and lead into invertebrate and fish tissue. Low variability in tissue concentrations and the absence of a concentration-dependent relationship is indicative of low metal bioavailability.
- Concentrations of mercury and selenium in fish tissue are below identified tissue residue screening levels for protection of fish or fish-eating wildlife.
- The low bioavailability of metals in Duck and Otter Creeks, despite bulk sediment concentrations that exceed PECs, is consistent with published results of spiked sediment toxicity studies and sediment toxicity investigations at contaminated sediment sites dominated by arsenic, chromium, and lead.

Taken together, the available information consistently shows that metals in Duck and Otter Creeks sediment are not likely to adversely affect benthic invertebrates.

6 PCBs

Comparisons of total PCB concentrations in sediment to the PEC screening value (MacDonald et al. 2000) are summarized in Table 6-1 and illustrated in Figure 6-1. Biota tissue concentrations are shown together with spatially paired sediment concentrations in Figures 6-2 and 6-3. The biological significance of the reported PCB concentrations is discussed below.

6.1 PCBs in Sediment

In Otter Creek, there are few locations where PCBs have been reported at concentrations exceeding the PEC, and those locations are not concentrated in any particular area of the creek. The highest total PCB concentration, 11.3 mg/kg, represents a sampled collected in 2007 from location OC-16. This location was resampled in 2010, and PCBs were not detectable. In Duck Creek, no PCB concentrations have been reported in excess of the PEC at any locations in the creek, but PCB concentrations are elevated in subsurface sediments within the Duck Creek confluence area. Total PCB concentrations exceeding the PEC in this area are buried beneath at least two feet of sediment, and in most cases beneath at least four feet of sediment containing lower PCB concentrations.

As described above for metals, the PEC for PCBs is not necessarily predictive of sediment toxicity due specifically to PCBs, although it can be viewed as typical of an overall level of sediment contamination by multiple chemicals. Fuchsman et al. (2006) reviewed cause-effect, concentration-response information for PCB effects on benthic invertebrates and proposed a set of equilibrium partitioning benchmarks for different PCB mixtures. In Duck and Otter Creeks, PCBs have generally been quantified as Aroclor 1248 and Aroclor 1254; of these, the PCB benchmark is more conservative for Aroclor 1248 (490 µg/gOC). For sediment containing 1% organic carbon, this benchmark corresponds to 4.9 mg/kg. For sediment containing 4.5% organic carbon (the average TOC content of Duck Creek subsurface sediment samples), the equilibrium partitioning benchmark is 22 mg/kg. The maximum total PCB concentration in subsurface sediment from the Duck Creek confluence area is 6.5 mg/kg. Given the observed TOC content, the PCBs in buried sediment in this area would have a low potential to affect invertebrates, in the unlikely event that they were to become exposed in the future.

Benthic invertebrates are not generally the most PCB-sensitive species, with fish and wildlife being more susceptible. As discussed below, current PCB exposures have not resulted in levels of concern in fish tissue, with respect to potential effects on the fish themselves. Effects on aquatic-feeding wildlife due to PCBs in Duck and Otter Creek sediments appear unlikely, because elevated concentrations of PCBs in surface sediment are few and scattered.

6.2 PCBs in Biota Tissue

Among the invertebrate tissue samples collected from Duck and Otter Creeks, total PCB concentrations were low (less than 0.1 mg/kg). Jarvinen and Ankley (1999) reviewed studies in which PCB concentrations in invertebrate tissue could be linked to adverse effects on invertebrates. Concentrations that could potentially cause toxicity in invertebrate tissue are more than an order of magnitude higher than the concentrations measured in invertebrates from Duck and Otter Creeks. For tests with Aroclors 1248 and 1254, invertebrate tissue PCB

concentrations associated with toxicity range from 3.9 mg/kg to 552 mg/kg, depending on the species and exposure duration.

Fish samples collected from Duck and Otter Creeks all contained less than 1 mg/kg total PCBs. Because fish are mobile, and PCB-contaminated sediments are present in other parts of the Maumee Area of Concern, fish collected from Duck and Otter Creeks may contain PCBs that originated outside Duck and Otter Creeks. Regardless, the reported total PCB concentrations in fish tissue are below levels associated with adverse effects on fish. A conservative comparison value is available from Hansen et al. (1974), who observed no effect on reproduction or fry survival associated with a parental whole-body Aroclor 1254 concentration of 1.9 mg/kg. Thus, the PCB tissue data for Duck and Otter Creeks indicates a low potential for PCB-related toxicity to aquatic life, consistent with the evaluation of sediment data presented above.

7 Other Chemicals

Cardno ENTRIX (2012) conducted a screening-level assessment of SVOCs and pesticides in Duck and Otter Creeks sediment, concluding that these chemical classes were unlikely to adversely affect aquatic organisms. That analysis is updated here for the larger sediment data set compiled for this supplemental data evaluation. The updated screening analysis also includes volatile organic compounds (VOCs), which were analyzed in a small number of sediment samples from Duck and Otter Creeks.

The screening evaluation used screening values from the following sources as available, in order of priority: (1) PECs from MacDonald et al. (2000); (2) equilibrium partitioning benchmarks from the DGI report; and (3) newly calculated equilibrium partitioning benchmarks. Equilibrium partitioning benchmarks were calculated according to the following equation:

$$SQB = WQB \times K_{oc} \qquad \text{Eqn. 2}$$

where

SQB = Sediment quality benchmark (µg/gOC)
WQB = Water quality benchmark (mg/L)
Koc = Organic carbon-water partition coefficient (liter per kilogram of organic carbon [L/kgOC])

Water quality benchmarks were identified from the following sources as available, in order of priority: (1) Ohio EPA OMZA, from Lake Erie Basin Aquatic Life Criteria; (2) Michigan Department of Environmental Quality FCVs (analogous to Ohio's OMZA values); (3) USEPA Region 5 Ecological Screening Level. K_{oc} values were identified using USEPA's online EPI Suite software, specifically the KOCWIN program. This program provides K_{oc} values estimated in two ways, based on the octanol-water partition coefficient and based on a molecular conductivity index. For conservatism, the lower of the two K_{oc} values was used in our assessment.

Although Equation 2 is appropriate for most organic compounds that persist in sediment, it is a mathematical simplification of chemical partitioning behavior, in that it assumes the measured bulk sediment chemical concentration to be equivalent to the concentration sorbed to sediment particles (i.e., the concentration dissolved in porewater is assumed to be such a small part of the total measured concentration as to be negligible). For relatively soluble compounds, this simplification introduces significant error, which is corrected with the following modified equilibrium partitioning equation (Fuchsman 2003, USEPA 2008):

$$SQB = WQB \times \left(K_{OC} + \frac{1-f_{solids}}{f_{solids}}\right) \qquad \text{Eqn. 3}$$

where f_{solids} is the solids content of the sediment, expressed as a fraction. Equation 3 was used for chemicals where (1) the K_{oc} was less than 1,000 (log K_{oc} < 3), and (2) an initial screening value calculated using Equation 2 was exceeded. Solids content was identified separately for each chemical, based on the percent solids in the sediment sample containing the highest detected concentration of that chemical. Table 7-1 identifies the sources of input parameters and the equation employed (standard or modified) for each chemical.

7.1 SVOCs and VOCs

All measured VOC concentrations in Duck and Otter Creeks were below the respective screening values. Three SVOCs were reported at concentrations exceeding the screening values presented in Table 7-1, namely dibenzofuran, di-n-butylphthalate, and 4-methylphenol. However, none of these SVOCs is likely to contribute significantly to sediment toxicity in Duck and Otter Creeks, for the reasons described below.

- Dibenzofuran. Only one sediment sample, collected from Envirosafe Site 1 in Otter Creek, contained dibenzofuran at a concentration exceeding the screening value. Because the screening value was exceeded in only 1% of samples, sediment management decisions need not be based on this chemical.

- Di-n-butylphthalate. The maximum detected concentration (50.9 µg/gOC) exceeds the screening value of 11 µg/gOC. However, in spiked sediment toxicity tests with the midge *Chironomus dilutus*, Call et al. (2001) observed no effects on survival or growth at di-n-butylphthalate concentrations up to 8,810 µg/gOC. Thus, it is very unlikely that di-n-butylphthalate contributed to observed effects on midges in toxicity tests with Duck and Otter Creek sediments.

- 4-Methylphenol. The screening value of 7.8 µg/gOC is exceeded in 10% of the sediment samples from Duck and Otter Creeks. However, the screening value is based on a water quality value that incorporates substantial uncertainty factors to account for limited toxicity data. An alternative screening value can be calculated for comparison purposes using the no-effect concentration from a 21-day reproduction test with the water flea, *Daphnia magna* (Kuhn et al. 1989). Multiplying the alternative water quality value of 1 mg/L by the Koc of 146.2 L/kgOC yields an alternative screening value of 146 µg/gOC. The maximum 4-methylphenol concentration from Duck and Otter Creeks was 137 µg/gOC, suggesting that 4-methylphenol is probably at most a secondary stressor for benthic invertebrates in Duck and Otter Creeks.

7.2 Pesticides

Based on the analysis presented in the DGI report (Cardno ENTRIX 2012) and summarized in Table 7-1, all detected concentrations of pyrethroid pesticides are below the respective screening values in Duck and Otter Creeks sediments. Pyrethroid pesticides were analyzed only in the 13 DGI sediment samples that were tested for toxicity.

Organochlorine pesticides were not analyzed as part of the GLLA 2010-2011 sampling program, because earlier data indicated that pesticide concentrations were not generally at levels that would influence sediment management decisions. This interpretation is borne out in the screening evaluation presented in Table 7-1. Two pesticides—gamma-chlordane and total DDT (i.e., DDT plus metabolites DDD and DDE)—exceeded the PEC screening values, each at a frequency of 4% of sediment samples. Because PECs do not necessarily reflect cause-effect, concentration-response relationships for specific chemicals, these pesticides are further evaluated below. Neither pesticide is likely to affect benthic invertebrates at the concentrations reported in Duck and Otter Creek sediments.

- Gamma-chlordane. USEPA (1980) identified an FCV for aquatic life protection of 0.17 µg/L for chlordane. Combined with a K_{oc} of 58,890 L/kgOC, this water quality value yields an equilibrium partitioning sediment benchmark of 10 µg/gOC. All gamma-chlordane concentrations reported from Duck and Otter Creeks are at least an order of magnitude lower than this alternative screening value.

- Total DDT. In a study of DDD toxicity, Ingersoll et al. (2004) conducted spiked sediment toxicity testing with *Chironomus dilutus* and performed field colonization tests with DDD-spiked sediments. These tests support a toxicity threshold of approximately 50 µg/gOC. Harkey et al. (1994) observed no effects on survival of midges (*Chironomus riparius*) exposed to 80 µg/gOC DDT. Concentrations of total DDT reported from Duck and Otter Creeks sediments are more than an order of magnitude lower than these values. Also, the maximum site-specific fish tissue concentration of total DDT (0.37 mg/kg wet weight; USFWS 2011) is below a fish tissue screening value of 0.6 mg/kg developed for protection of fish reproduction (Beckvar et al. 2005). Taken together, these findings indicate a low potential for DDT-related effects on aquatic organisms in Duck and Otter Creeks.

8 Conclusions

This evaluation of Duck and Otter Creeks chemical and biological analyses integrated data from seven sampling programs conducted between 2006 and 2011. The findings of this evaluation support the following conclusions:

- Sediment toxicity to benthic invertebrates is observed in downstream portions of Otter Creek and the confluence area where Otter Creek enters Maumee Bay.
- Concentrations of PAHs in sediment porewater are sufficient to explain the observed toxicity in this area, even though bulk sediment PAH concentrations are not predictive of toxicity. A threshold for sediment toxicity was identified as a porewater PAH TU value of 5.
- Porewater PAH TUs are closely correlated with concentrations of DRO, with a DRO concentration of 3,100 mg/kg corresponding to the porewater PAH threshold of 5 TU. Elevated concentrations of PAHs in porewater are also associated with observations of sheen during sediment sampling and with a petrogenic chemical fingerprint.
- The combination of porewater PAH and sediment DRO results supports delineation of areas where sediment toxicity is predicted in lower Otter Creek and the Otter Creek confluence area. In Duck Creek, elevated DRO concentrations are almost exclusively found in buried sediments, which do not come into contact with organisms.
- Metals exhibit low bioavailability in Duck and Otter Creek sediments, based on several lines of evidence. Sediment management to address elevated concentrations of metals in Duck and Otter Creek sediments is not warranted.
- Concentrations of PCBs, SVOCs, VOCs, pyrethroid pesticides, and organochlorine pesticides in Duck and Otter Creek sediments also are not expected to adversely affect aquatic organisms.

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Tables

Table 3-1. Summary of Sediment Toxicity Test Results, 2010-2011

Sample	Survival (%)	Ash-free Dry Weight per Surviving Organism (mg)	Ash-Free Biomass/Initial Organism (mg)	Paired Control	Mean Ash-Free Biomass (% of Control)
DC-3	70.0 ± 29.4	1.80 ± 0.31	1.21± 0.40	1	89.6
DC-5	87.1 ± 11.1	1.28 ± 0.14[a]	1.11 ± 0.18	2	78.7
DC-6/7	83.8 ± 17.7	2.42 ± 0.73	1.96 ± 0.49	3	69.0
DC-11/12	83.8 ± 19.2	1.92 ± 0.72	1.54 ± 0.40	3	54.2
DC-13	87.5 ± 16.7	2.92 ± 0.89	2.59 ± 1.02	5	91.2
DC-14	81.3 ± 19.6	2.04 ± 0.68	1.68 ± 0.79	6	95.5
DC-16	83.8 ± 16.0	2.35 ± 0.58	1.93 ± 0.42	6	109.7
DC-17	83.8 ± 14.1	2.24 ± 0.68	1.86 ± 0.57	6	105.7
DC-19	73.8 ± 16.0	2.41 ± 0.45	1.78 ± 0.58	6	101.1
DC-22	95.0 ± 7.6	0.980 ± 0.093	0.937 ± 0.088	8	98.9
DC-23	95.0 ± 7.6	0.916 ± 0.155	0.864 ± 0.103	8	91.2
DC-25	88.8 ± 8.3	0.744 ± 0.149[b]	0.655 ± 0.120[c]	8	69.2[c]
OC-4	41.3 ± 25.3[a]	0.27 ± 0.08[a]	0.12 ± 0.04[a]	1	8.9[a]
OC-5A-01	70.0 ± 23.3	0.36 ± 0.14[a]	0.26 ± 0.16[a]	1	19.3[a]
OC-6/7	78.8 ± 33.6	1.31 ± 0.13	1.18 ± 0.23	1	87.4
OC-9-10	82.9 ± 18.0	0.80 ± 0.12	0.66 ± 0.24[a]	1	48.9[a]
OC-12/13	92.9 ± 9.5	1.37 ± 0.20	1.26 ± 0.11	2	89.4
OC-16	91.4 ± 9.0	1.31 ± 0.30[a]	1.19 ± 0.26	2	84.4
OC-22	91.3 ± 9.9	2.64 ± 0.55	2.43 ± 0.63	3	85.6
OC-24/25	81.3 ± 23.6	2.73 ± 0.58	2.29 ± 0.90	3	80.6
OC-26	17.5 ±20.5[c]	0.46 ± 0.09[c]	0.077 ± 0.09[c]	6	4.4[c]
OC-27	0 ± 0[a]	NA	0 ± 0[a]	7	0.0[a]
OC-28	83.8 ± 14.1	0.54 ± 0.16[c]	0.46 ± 0.18[b]	7	39.3[b]
OC-29	66.3 ± 13.0	0.15 ± 0.02[c]	0.09 ± 0.01[c]	7	7.7[c]
OC-30	60.0 ± 21.4[b]	0.19 ± 0.06[c]	0.11 ± 0.05[c]	7	9.4[c]
OC-31	70.0 ± 28.3	0.90 ± 0.25[b]	0.68 ± 0.37	7	58.1
OC-35	92.5 ± 11.6	0.847 ± 0.237[b]	0.764 ± 0.120[b]	8	80.1[b]
OC-38	86.3 ± 10.6	0.761 ± 0.194[b]	0.645 ± 0.121[c]	8	68.1[c]
OC-40	91.3 ± 11.3	1.095 ± 0.275	0.993 ± 0.263	8	104.9
OC-41	86.3 ± 15.1	0.968 ± 0.234	0.810 ± 0.135[b]	8	85.5[b]
OC-42	13.8 ± 16.0[c]	0.122 ± 0.034[c]	0.016 ± 0.019[c]	8	1.7[c]
OC-44	52.5 ± 29.6[b]	0.445 ± 0.152[c]	0.256 ± 0.197[c]	8	27.0[c]
OC-45	90.0 ± 14.1	0.825 ± 0.160[b]	0.731 ± 0.130[b]	8	77.2[b]
OC-46	95.0 ± 5.3	0.689 ± 0.104[c]	0.653 ± 0.094[c]	8	69.0[c]
OC-49	41.3 ± 30.0[a]	0.277 ± 0.091[a]	0.110 ± 0.087[a]	9	8.4[a]
OC-50	47.5 ± 14.9[a]	0.283 ± 0.153[a]	0.138 ± 0.112[a]	9	10.5[a]
OC-51	78.8 ± 34.4	1.146 ± 0.279	0.877 ± 0.378[a]	9	66.6[a]
OC-52	40.0 ± 31.2[a]	0.291 ± 0.133[a]	0.122 ± 0.136[a]	9	9.3[a]
OC-53	92.5 ± 10.4	1.318 ± 0.248	1.211 ± 0.224	9	92.0
OC-54	97.5 ± 4.6	1.270 ± 0.156	1.237 ± 0.159	9	93.9
OC-55	92.5 ± 8.9	1.328 ± 0.154	1.228 ± 0.184	9	93.2
OC-56	93.8 ± 7.4	1.286 ± 0.149	1.200 ± 0.113	9	91.1
OC-57	90.0 ± 10.7	1.245 ± 0.178	1.121 ± 0.215	9	85.1
OC-58	96.3 ± 7.4	1.308 ± 0.191	1.250 ± 0.128	9	94.9
OC-59	91.3 ± 8.3	1.356 ± 0.238	1.225 ± 0.173	9	93.0
OC-60	91.3 ± 13.6	1.421 ± 0.329	1.268 ± 0.214	9	96.3
OC-61	95.0 ± 7.6	1.452 ± 0.187	1.370 ± 0.115	9	104.0
GC-1[d]	85.0 ± 18.7	1.37 ± 0.30	1.14 ± 0.25	4	100.9
AD-1[d]	80.0 ± 14.1	1.72 ± 0.32	1.37 ± 0.31	4	121.2
Control 1	93.8 ± 7.4	1.50 ± 0.39	1.35 ± 0.35	1	NA
Control 2	82.5 ± 8.9	1.81 ± 0.48	1.41 ± 0.22	2	NA
Control 3	87.5 ± 14.9	3.10 ± 1.12	2.84 ± 1.40	3	NA
Control 4	82.5 ± 13.9	1.39 ± 0.22	1.13 ± 0.19	4	NA
Control 5	87.5 ± 14.9	3.10 ± 1.12	2.84 ± 1.40	5	NA
Control 6	81.3 ± 6.4	2.39 ± 0.81	1.76 ± 0.64	6	NA

Table 3-1. Summary of Sediment Toxicity Test Results, 2010-2011

Sample	Survival (%)	Ash-free Dry Weight per Surviving Organism (mg)	Ash-Free Biomass/Initial Organism (mg)	Paired Control	Mean Ash-Free Biomass (% of Control)
Control 7	78.8 ± 9.9	1.45 ± 0.48	1.17 ± 0.51	7	NA
Control 8	88.8 ± 8.3	1.077 ± 0.169	0.947 ± 0.097	8	NA
Control 9	93.8 ± 9.2	1.431 ± 0.330	1.317 ± 0.179	9	NA

Results represent mean ± 1 standard deviation

a. Statistically different from control based on ERDC analysis (Weston did not conduct analysis)

b. Statistically different from control based on Weston analysis only

c. Statistically different from control based on ERDC and Weston analyses

d. Sediment samples from urban comparison locations (AD-1 and GC-1) were re-tested for toxicity due to excessive presence of indigenous predatory flatwors in initial tests. Re-test results are shown here.

Table 3-2. Ranking of Benthic Invertebrate Community Metric Results, 2010 Sampling Results

Station	Taxa Richness Result	Taxa Richness Rank	Percent Sensitive Result	Percent Sensitive Rank	Percent Tolerant Result	Percent Tolerant Rank	Average Rank
AD	7	6	61	1	24	2	3
GC	9	2	1	8	80	9	6
DC-3	8	4	18	2	43	3	3
DC-5	8	4	17	3	73	6	4
DC-6/7	7	6	1	8	70	4	6
OC-4	4	12	0	13	77	8	11
OC-5A	5	11	0	13	100	13	12
OC-6/7(2)	2	13	0	13	96	12	13
OC-9/10	5	11	1	8	77	8	9
OC-12/13	5	11	0	13	72	5	10
OC-16	5	11	0.3	9	83	11	10
OC-22	6	7	1	8	83	11	9
OC-24/25	12	1	3	4	19	1	2

Table 3-3. Comparison of Sediment Toxicity, Benthic Community, and Porewater PAHs, 2010 Sampling Results

Station	Toxic?	Benthic Rank	Porewater PAH TU >1?
AD	No	3	No
GC	No	6	No
DC-3	No	3	No
DC-5	No	4	No
DC-6/7	No	6	No
OC-4	Yes	11	Yes
OC-5A	Yes	12	Yes
OC-6/7(2)	No	13	Yes
OC-9/10	Yes	9	Yes
OC-12/13	No	10	No
OC-16	No	10	No
OC-22	No	9	No
OC-24/25	No	2	No

PAH: polycyclic aromatic hydrocarbon
TU: toxic unit
Shading indicates differences in degree of apparent impact or benthic quality.

Table 3-4. Summary of Ohio EPA 2006-2008 Biological Monitoring Results[a]

Location Name	Location ID (RM)[b]	Drainage Area (mi^2)	QHEI	Invertebrates		Fish			
				Qualitative Rating	# of Species Collected	IBI	DELT	# of Individuals Collected	# of Species Collected
Otter Creek-Oakdale Ave.	S03P12 (6.0)	2.8[H]	23.0	VP*	12	16*	0.0	109	4
Otter Creek-Yarrow St./Consaul St.	S03P08 (3.1/3.0)	5.8[H]	25.5	VP*	15	18*	0.0	99	7
Otter Creek-Millard Rd.	S03P05 (2.2/2.1)	6.6[H]	30.0	VP*	13	28	0.0	27	8
Otter Creek-Adjacent CSX Road-Near Mouth	S03S25 (0.5)	7.4[B]	35.0	NR	NR	36[d]	0.0[d]	327[d]	23[d]
Duck Creek-Consaul St.	P11K22 (3.10)	0.6[H]	30.0	VP*	23	12*	0.0	5	3
Duck Creek-York St.	P11S56 (2.52)[c]	0.8[H]	22.0	VP*	22	12*	0.0	19	4

a. Data source for Table 3-4: Ohio EPA (2010)

b. River mile (RM) represents the Point of Record for the station, not the actual sampling RM

c. River mile in the appendix is reported as 2.40

d. Represents the average of two sampling efforts

* Indicates significant departure from applicable biocriteria. Underlined scores are in the Poor or Very Poor range

B: Boat Site

DELT: percentage of fish exhibiting deformities, fin erosions, lesions, and tumors

H: Headwater Site

IBI: Index of Biotic Integrity

NR: Not reported

QHEI: qualitative habitat evaluation index

VP: Very Poor

Table 4-1. Summary of PAH and Petroleum Hydrocarbon Concentrations in Duck Creek Surface Sediment

Chemical	All data			2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Units	Minimum Detect	Maximum Detect	Average	Minimum Detect	Maximum Detect	Average	Benchmark	Frequency of Exceedance
Polycyclic Aromatic Hydrocarbons											
Total PAH-16	50	50	mg/kg	2.8	1934	126.3	0.7	91	17.3	22.8	20%
Total PAH-16	49	49	mg/kg at 1% TOC	0.2	401	25.3	0.1	45	5.3	22.8	20%
Total PAHs-34[a]	28	28	mg/kg	13.7	2386	359.8	1.2	121	23.8	NV	NV
Total PAHs-34[a]	28	28	mg/kg at 1% TOC	0.8	495	77.1	0.1	4	1.6	NV	NV
ESBTU	28	28	unitless	0.1	63	9.9	0.0	0.5	0.2	1	14%
Porewater PAH TU	13	15	unitless	NA	NA	NA	0.2	2	0.3	1	7%
Petroleum Hydrocarbons											
Oil & Grease	9	18	mg/kg	1340.0	12600	3650.0	NA	NA	NA	NV	NV
Diesel Range Organics (DRO)	21	21	mg/kg	NA	NA	NA	110	1300	409.5	NV	NV
Gasoline Range Organics (GRO)	2	21	mg/kg	NA	NA	NA	7.9	12	6.4	NV	NV
Residual Range Organics (RRO)	21	21	mg/kg	NA	NA	NA	580	3600	1901.0	NV	NV

a. 33 PAHs were analyzed in the Envirosafe 2006-2007 sampling event.

ESBTU: equilibrium partitioning sediment benchmark toxic units
GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilogram
NA: not analyzed
NV: screening value not available
PAHs: polycyclic aromatic hydrocarbons
TOC: total organic carbon
TU: toxic units

Table 4-2. Summary of PAH and Petroleum Hydrocarbon Concentrations in Duck Creek Sediment Cores

Chemical	All data			2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Units	Minimum Detect	Maximum Detect	Average	Minimum Detect	Maximum Detect	Average	Benchmark	Frequency of Exceedance
Polycyclic Aromatic Hydrocarbons											
Total PAH-16	47	52	mg/kg	NA	NA	NA	0.1	20	5.4	22.8	0%
Total PAH-16	47	52	mg/kg at 1% TOC	NA	NA	NA	0.0	6	1.6	22.8	0%
Petroleum Hydrocarbons											
Diesel Range Organics (DRO)	54	54	mg/kg	NA	NA	NA	31	21000	1611.9	NV	NV
Gasoline Range Organics (GRO)	24	54	mg/kg	NA	NA	NA	7.3	980	30.9	NV	NV
Residual Range Organics (RRO)	54	54	mg/kg	NA	NA	NA	69	19000	2307.0	NV	NV

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilogram
NA: not analyzed
NV: screening value not available
TOC: total organic carbon

Table 4-3. Summary of PAH and Petroleum Hydrocarbon Concentrations in Otter Creek Surface Sediment

Chemical	All data			2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Units	Minimum Detect	Maximum Detect	Average	Minimum Detect	Maximum Detect	Average	Benchmark	Frequency of Exceedance
Polycyclic Aromatic Hydrocarbons											
Total PAH-16	108	109	mg/kg	3.2	249	37.5	0.2	56	10.7	22.8	27%
Total PAH-16	109	110	mg/kg at 1% TOC	0.3	48	7.7	0.1	27	3.8	22.8	26%
Total PAHs-34[a]	69	69	mg/kg	29.9	294	85.2	0.4	397	37.0	NV	NV
Total PAHs-34[a]	69	69	mg/kg at 1% TOC	2.7	56	19.9	0.2	107	10.5	NV	NV
ESBTU	69	69	unitless	0.3	7	2.5	0.0	15	1.4	1	35%
Porewater PAH TU	41	41	unitless	NA	NA	NA	0.2	170	20.5	1	59%
Petroleum Hydrocarbons											
Oil & Grease	26	28	mg/kg	1100.0	13100	4347.3	NA	NA	NA	NV	NV
Diesel Range Organics (DRO)	40	40	mg/kg	NA	NA	NA	110	16000	2755.5	NV	NV
Gasoline Range Organics (GRO)	17	40	mg/kg	NA	NA	NA	17	1600	116.4	NV	NV
Residual Range Organics (RRO)	39	40	mg/kg	NA	NA	NA	91	22000	3252.2	NV	NV

a. 33 PAHs were analyzed in the Envirosafe 2006-2007 sampling event.

ESBTU: equilibrium partitioning sediment benchmark toxic units
GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilogram
NA: not analyzed
NV: screening value not available
PAHs: polycyclic aromatic hydrocarbons
TOC: total organic carbon
TU: toxic units

Table 4-4. Summary of PAH and Petroleum Hydrocarbon Concentrations in Otter Creek Sediment Cores

Chemical	All data			2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Units	Minimum Detect	Maximum Detect	Average	Minimum Detect	Maximum Detect	Average	Benchmark	Frequency of Exceedance
Polycyclic Aromatic Hydrocarbons											
Total PAH-16	85	107	mg/kg	NA	NA	NA	0.0	167	7.4	22.8	6%
Total PAH-16	85	107	mg/kg at 1% TOC	NA	NA	NA	0.0	18	2.4	22.8	6%
Petroleum Hydrocarbons											
Diesel Range Organics (DRO)	57	58	mg/kg	NA	NA	NA	26	60000	5218	NV	NV
Gasoline Range Organics (GRO)	34	58	mg/kg	NA	NA	NA	19	7000	326	NV	NV
Residual Range Organics (RRO)	58	58	mg/kg	NA	NA	NA	25	64000	4596	NV	NV

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilogram
NA: not analyzed
NV: screening value not available
TOC: total organic carbon

Table 4-5. Field Observations for Sediment Sample Locations, 2010-2011

Location	Sample Date	Water Depth	Sediment Thickness	Sediment Depth						General Observations
				Surface	0-24"	24-48"	48-72"	72-96"	96-120"	
OC-1A	10/4/2010	3.9'	48"	NR	odor	odor	--	--	--	NR
OC-1A	10/6/2010	12"	1'5"	NR	odor	--	--	--	--	NR
OC-2	10/6/2010	12"	3'3"	NR	odor	24-39": none	--	--	--	odor
OC-2A	10/6/2010	6-12"	5'2"	NR	odor	odor	48-62": none	--	--	odor
OC-3	10/7/2010	NR	2'5"	NR	odor	24-30": none	--	--	--	sheen on water and odor
OC-3A	10/7/2010	2.5'	3'10"	NR	odor	24-40": odor; 40-	--	--	--	sheen on water and odor
OC-4	10/7/2010	3'	3'6"	NR	sheen on water and odor	24-42": odor	--	--	--	sheen on water and odor
OC-4A	10/7/2010	3'	2'9.5"	NR	odor	24-41": odor	--	--	--	sheen on water
OC-5	10/8/2010	2.5'	3'11"	NR	odor	24-47": none	--	--	--	sheen on water and odor
OC-5A	10/8/2010	2.5'	3'10"	NR	odor	24-46": none	--	--	--	odor and sheen
OC-6	10/11/2010	2.5'	3'5"	NR	odor	24-41": none	--	--	--	NR
OC-6/7(1)	10/11/2010	2.5'	3'9.5"	odor	odor	24-45.5": odor	--	--	--	NR
OC-6/7(2)	10/11/2010	1'5"	1'	NR	0-12": sheen on water and odor	--	--	--	--	NR
OC-7/8	10/7/2010	6"	NR	NR	--	--	--	--	--	odor
OC-8	10/12/2010	12"	24"	NR	odor	--	--	--	--	NR
OC-8/9	10/7/2010	1.5'	NR	NR	--	--	--	--	--	odor
OC-9	10/18/2010	6"	8"	NR	0-8": none	--	--	--	--	NR
OC-9/10	10/7/2010	1.5'	NR	NR	--	--	--	--	--	odor
OC-10/11	10/7/2010	1'	NR	NR	--	--	--	--	--	none

Table 4-5. Field Observations for Sediment Sample Locations, 2010-2011

Location	Sample Date	Water Depth	Sediment Thickness	Sediment Depth						General Observations
				Surface	0-24"	24-48"	48-72"	72-96"	96-120"	
OC-11/12	10/15/2010	NR	NR	odor and sheen	--	--	--	--	--	NR
OC-12/13	10/15/2010	1'3"	NR	NR	--	--	--	--	--	none
OC-15/16	10/19/2010	1-1.5'	NR	none	--	--	--	--	--	none
OC-16	10/15/2010	1'	NR	none	--	--	--	--	--	odor and sheen (deeper sediment)
OC-16/17	10/19/2010	1'	NR	NR	--	--	--	--	--	none
OC-18	10/18/2010	1'	1'9"	NR	0-21": odor	--	--	--	--	NR
OC-18/19	10/19/2010	1'	NR	NR	--	--	--	--	--	none
OC-22	10/19/2010	1'	NR	NR	--	--	--	--	--	sheen
OC-23	10/18/2010	1'	2'7"	NR	odor	24-27": odor	--	--	--	odor and sheen
OC-24/25	10/19/2010	1.5'	NR	NR	--	--	--	--	--	sheen
DC-1	10/12/2010	3'	36"	NR	0-23": none	23-36": odor	--	--	--	odor
DC-2	10/12/2010	8"	42.5"	NR	NR	24-42.5": NR	--	--	--	odor
DC-3	10/13/2010	6"	24"	NR	none	--	--	--	--	NR
DC-3/4	10/13/2010	6"	25"	NR	none	--	--	--	--	NR
DC-4	10/13/2010	6"	24"	NR	none	--	--	--	--	NR
DC-5	10/14/2010	1'	4'4"	NR	odor	odor	48-52": none	--	--	odor
DC-5/6	10/15/2010	2'	NR	none	--	--	--	--	--	NR
DC-6/7	10/19/2010	2'	NR	NR	--	--	--	--	--	none
DC-7/8	10/15/2010	1'	NR	none	--	--	--	--	--	NR

Table 4-5. Field Observations for Sediment Sample Locations, 2010-2011

Location	Sample Date	Water Depth	Sediment Thickness	Sediment Depth						General Observations
				Surface	0-24"	24-48"	48-72"	72-96"	96-120"	
DC-7/8 dup	10/15/2010	1'	NR	none	--	--	--	--	--	NR
DC-8	10/18/2010	18"	1'8"	NR	0-20": none	--	--	--	--	NR
DC-9/10	10/15/2010	12"	NR	none	--	--	--	--	--	NR
DC-10/11	10/19/2010	1'	NR	NR	--	--	--	--	--	none
DC-11	10/18/2010	24"	10"	NR	0-10": none	--	--	--	--	NR
DC-11/12[a]	NR	NR	NR	NR	--	--	--	--	--	NR
DC-20	5/11/2011	5.5'	3.6'	NR	none	24-36": none	--	--	--	NR
DC-21	5/11/2011	4'	4'	none	0-21": none	--	--	--	--	NR
DC-22	5/11/2011	4.8'	9.7'	NR	NR	24-39": none	--	--	--	odor and sheen
DC-23	5/11/2011	7.4'	8.1'	NR	none	none	48-57": none	--	--	none
DC-24	5/11/2011	8.0'	6.4'	NR	odor	24-53": none	--	--	--	organic odor
DC-25	5/11/2011	3.6'	7.7'	NR	NR	--	--	--	--	odor and sheen
OC-34	5/10/2011	3.3'	5.5'	NR	0-26": odor	--	--	--	--	none
OC-35	5/12/2011	4.5'	2.0'	NR	odor and sheen	--	--	--	--	odor and sheen
OC-36	5/10/2011	2.5'	1.5'	NR	0-15": none	--	--	--	--	NR
OC-37	5/11/2011	1.5'	≤0.5'	NR	--	--	--	--	--	NR
OC-38	5/11/2011	2.1'	8"	NR	none	--	--	--	--	NR
OC-39	5/11/2011	1.5'	≤4"	NR	--	--	--	--	--	NR

Table 4-5. Field Observations for Sediment Sample Locations, 2010-2011

Location	Sample Date	Water Depth	Sediment Thickness	Sediment Depth						General Observations
				Surface	0-24"	24-48"	48-72"	72-96"	96-120"	
OC-40	5/11/2011	3.9'	1.1'	NR	0-23": none	--	--	--	--	NR
OC-41	5/10/2011	3.2'	2.1'	NR	0-23": none	--	--	--	--	NR
OC-42	5/11/2011	3.6'	2.1'	NR	0-26": odor and sheen	--	--	--	--	odor and sheen
OC-43	5/11/2011	3.9'	2.7'	NR	--	--	--	--	--	odor and sheen
OC-44	5/10/2011	4.3'	3.8'	NR	0-27": odor and sheen	--	--	--	--	sheen
OC-45	5/10/2011	3.9'	3.6'	NR	0-34": odor and sheen	--	--	--	--	odor
OC-46	5/12/2011	5.0'	3.6'	NR	none	none	--	--	--	none
OC-47	5/12/2011	5.4'	10.6'	NR	organic odor	none	48-64": none	--	--	none
OC-48	5/12/2011	5.7'	11.5'	NR	none	none	48-74": none	--	--	none
OC-49	10/18/2011	2'11"	4'	odor and sheen	odor and sheen	31-58": none	--	--	--	NR
OC-50	10/18/2011	2'6"	6'6"	odor and sheen	odor and sheen	odor and sheen	48-63": none	--	--	NR
OC-50 dup	10/18/2011	2'6"	6'6"	odor	odor and sheen	odor and sheen	48-63": none	--	--	NR
OC-51	10/18/2011	3'9"	~4'	odor	odor	24-44": none	--	--	--	NR
OC-52	10/18/2011	2'10"	5'	odor and sheen	odor	none	48-64": none	--	--	NR
OC-52 dup	10/18/2011	2'10"	5'	odor and sheen	odor	none	48-65": none	--	--	NR
OC-53	10/18/2011	4'2"	32"	odor and sheen	odor	24-32": none	--	--	--	NR
OC-54	10/18/2011	3'3"	6'	none	odor, sheen, and visible oil	odor, sheen, and visible	48-65": none	--	--	NR
OC-55	10/18/2011	4'10"	3.5'	none	odor	24-42": none	--	--	--	NR

Table 4-5. Field Observations for Sediment Sample Locations, 2010-2011

Location	Sample Date	Water Depth	Sediment Thickness	Sediment Depth						General Observations
				Surface	0-24"	24-48"	48-72"	72-96"	96-120"	
OC-56	10/18/2011	5'8"	113"	odor and sheen	odor and visible oil	odor and visible oil	odor	odor	96-112": odor	NR
OC-57	10/18/2011	5'	10'	odor and sheen	odor, sheen, and visible oil	odor, sheen, and visible	odor, sheen, and visible	odor, sheen, and visible	odor, sheen, and visible	NR
OC-58	10/18/2011	6'1"	115"	none	odor	odor	odor	odor and sheen	96-121": odor	NR
OC-59	10/18/2011	5'10"	10'	NR	odor	odor and sheen	odor and sheen	odor and sheen	96-121": odor and	NR
OC-60	10/18/2011	6'11"	112"	odor and sheen	odor and sheen	odor and sheen	odor and sheen	odor	96-121": odor	NR
OC-61	10/18/2011	8'3"	115"	none	odor	odor	odor	odor	96-122": odor	NR
DC-13	11/2/2010	2'4"	~8'	none	none	none	none	odor	none	NR
DC-14	11/3/2010	6'6"	>10'	odor	none	none	none	none	96-122": odor	NR
DC-16	11/2/2010	5'2"	>10'	none	none	odor	none	none	none	12'-167": odor
DC-17	11/2/2010	5'10"	>10'	none	none	none	none	odor	none	10-12': odor
DC-19	11/2/2010	7'1"	>10'	none	none	none	none	none	8' to 127': odor	NR
OC-26	11/3/2010	1'10"	~3'	NR	odor	24-49": odor	--	--	--	odor and sheen
OC-26 dup	11/3/2010	1'10"	~3'	NR	odor	24-47": odor	--	--	--	odor and sheen
OC-27	11/3/2010	1'9"	~4'	sheen	odor	24-50": odor	--	--	--	odor and sheen
OC-28	11/3/2010	2'6"	~4'	sheen	odor	none	48-62": odor	--	--	odor and sheen
OC-29	11/4/2010	2'6"	~4'	odor and sheen	odor and sheen	24-52": none	--	--	--	NR
OC-30	11/4/2010	3'0"	~4'	odor	odor	24-42": none	--	--	--	NR
OC-31	11/4/2010	3'4"	~4'	none	odor	none	--	--	--	NR

Table 4-5. Field Observations for Sediment Sample Locations, 2010-2011

Location	Sample Date	Water Depth	Sediment Thickness	Sediment Depth						General Observations
				Surface	0-24"	24-48"	48-72"	72-96"	96-120"	
OC-32	11/4/2010	3'3"	~3'	odor	none	24-30": none	--	--	--	NR
OC-33	11/4/2010	3'9"	~4'	none	none	24-39": none	--	--	--	NR

a. Field notes for this location are missing
NR: not reported
-- no sample from the designated depth interval
': foot
": inch

Table 4-6. Summary of Fish Tissue Sample Physical and Chemical Parameters

Fish Sampling Zone	Sample ID	Species	Number of Individuals	Length of Individuals (mm)	Composite Sample Weight (g)	C3-Napthalenes (mg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Total PCBs (mg/kg)
Duck A	DCA BG-1-C4	Bluegill	2	86 - 173	152	0.0043	0.1	0.34	0.1	0.17
Duck A	DCA LMB-3-I	Largemouth Bass	1	335	615	0.0059	0.31	0.05	0.07	0.9
Duck A	DCA LMB-4-C3	Largemouth Bass	3	169 - 126 - 119	409	0.0079	0.24	0.05	0.09	0.416
Duck A	DCA LMB-5-C2	Largemouth Bass	2	245 - 246	475	0.0066	0.23	0.05	0.025	0.498
Duck A	DCA LMB-6-C5	Largemouth Bass	5	162 - 241	520	0.0059	0.22	0.05	0.08	0.381
Duck A	DCA LP-1-C93	Log Perch	93	65 - 101	301	0.0089	0.21	0.2	0.09	0.276
Duck A	DCA PS-1-C2	Pumpkin Seed	2	176 - 152	217	0.0057	0.22	0.35	0.1	0.323
Duck A	DCA YP-1-C2	Yellow Perch	2	133 - 223	166	0.0037	0.025	0.3	0.07	0.496
Duck A	DCA-LMB1-I	Largemouth Bass	1	345	670	0.0058	0.3	0.05	0.06	0.721
Duck A	DCA-LMB2-I	Largemouth Bass	1	343	641	0.0063	0.22	0.05	0.025	1.06
Duck D	DCD-CCH1-C	Creek Chub	11	103 - 155	205	0.00099	0.08	0.1	0.08	0.106
Duck D	DCD-LMB1-C	Largemouth Bass	2	178 - 196	220	0.002	0.1	0.35	0.06	0.159
Duck E	DCE-BLG1-C	Bluegill	9	104 - 129	255	0.000985	0.1	0.3	0.23	0.217
Duck E	DCE-BLG2-C	Bluegill	9	91 - 126	275	0.001	0.1	0.78	0.1	0.132
Duck E	DCE-BLG3-C	Bluegill	10	91 - 129	290	0.000975	0.17	0.3	0.21	0.271
Duck E	DCE-BLG4-C	Bluegill	10	98 - 126	290	0.00098	0.1	0.42	0.1	0.225
Duck E	DCE-BLG5-C	Bluegill	9	102 - 120	250	0.000995	0.1	0.1	0.1	0.195
Duck E	DCE-BLG6-C	Bluegill	8	95 - 120	220	0.0022	0.16	0.45	0.13	0.226
Duck E	DCE-LMB1-I	Largemouth Bass	1	351	675	0.0026	0.025	0.05	0.06	0.905
Duck E	DCE-LMB2-I	Largemouth Bass	1	312	520	0.002	0.025	0.05	0.06	0.674
Duck E	DCE-LMB3-I	Largemouth Bass	1	374	1,000	0.0027	0.06	0.05	0.05	1.4
Duck E	DCE-LMB4-I	Largemouth Bass	1	418	1,250	0.0038	0.03	0.05	0.07	1.27
Duck E	DCE-LMB5-I	Largemouth Bass	1	393	1,050	0.004	0.07	0.1	0.07	1.05
Duck E	DCE-LMB6-C	Largemouth Bass	7	92 - 188	340	0.00099	0.07	0.3	0.07	0.159
Duck E	DCE-PS2-C	Pumpkin Seed	8	112 - 141	315	0.0025	0.16	0.3	0.1	0.349
Duck E	DCE-YP1-I	Yellow Perch	1	203	75	0.000995	0.07	0.38	0.2	0.196
Otter A	OCA-BG1-C	Bluegill	4	119 - 149	270	0.0144	0.1	0.39	0.38	0.61
Otter A	OCA-CRP1-I	Common Carp	1	683	2,200	0.0159	0.48	0.1	0.8	0.826

Table 4-6. Summary of Fish Tissue Sample Physical and Chemical Parameters

Fish Sampling Zone	Sample ID	Species	Number of Individuals	Length of Individuals (mm)	Composite Sample Weight (g)	C3-Napthalenes (mg/kg)	Arsenic (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Total PCBs (mg/kg)
Otter A	OCA-CRP2-I	Common Carp	1	550	2,200	0.0419	0.35	0.1	0.2	1.55
Otter A	OCA-CRP3-C	Common Carp	5	92 - 178	290	0.0138	0.24	0.47	0.2	0.27
Otter A	OCA-LMB1-I	Largemouth Bass	1	315	550	0.0332	0.22	0.05	0.09	1.14
Otter A	OCA-LMB2-I	Largemouth Bass	1	242	240	0.0182	0.18	0.31	0.025	1.35
Otter A	OCA-LMB3-C	Largemouth Bass	3	150 - 184	230	0.0154	0.07	0.2	0.02	0.607
Otter A	OCA-LMB5-C	Largemouth Bass	2	224 - 225	330	0.017	0.1	0.42	0.07	0.992
Otter A	OCA-LMB6-I	Largemouth Bass	1	238	230	0.0189	0.15	0.3	0.05	0.776
Otter A	OCA-LP1-C	Log Perch	37	unknown[a]	130	0.0694	0.21	0.34	0.18	0.608
Otter A	OCA-PS1-C	Pumpkin Seed	4	142 - 150	290	0.0164	0.1	0.44	0.19	0.601
Otter A	OCA-PS2-C	Pumpkin Seed	4	131 - 160	280	0.0151	0.1	0.33	0.17	0.64
Otter A	OCA-PS3-C	Pumpkin Seed	10	85 - 122	290	0.0109	0.21	0.3	0.17	0.637
Otter A	OCA-WS1-C	White Sucker	2	194 - 252	260	0.01	0.1	0.49	0.23	0.369
Otter A	OCA-WS2-C	White Sucker	5	172 - 180	340	0.0059	0.14	0.55	0.26	0.354
Otter A	OCA-WS3-C	White Sucker	5	155 - 185	310	0.0047	0.13	0.37	0.28	0.292
Otter A	OCA-WS4-C	White Sucker	5	144 - 189	280	0.0046	0.1	0.96	0.36	0.211
Otter A	OCA-YB1-I	Yellow Bullhead	1	241	200	0.0068	0.07	0.41	0.25	0.518
Otter A	OCA-YB2-I	Yellow Bullhead	1	250	240	0.0114	0.05	0.2	0.06	0.417
Otter A	OCA-YP5-C	Yellow Perch	7	121 - 161	200	0.0052	0.025	0.3	0.1	0.585
Otter C	OCC-CCH1-C2	Creek Chub	2	185 - 220	200	0.0115	0.07	0.32	0.24	0.472
Otter C	OCC-CCH2-C8	Creek Chub	8	102 - 148	156	0.0129	0.16	0.3	0.24	0.429
Otter D	OCD-BG1-C6	Bluegill	6	72 - 106	85	0.0034	0.17	0.5	0.13	0.377
Otter D	OCD-CCH1-C5	Creek Chub	5	133 - 189	280	0.0072	0.09	0.1	0.07	0.676
Otter D	OCD-CCH2-C7	Creek Chub	7	109 - 174	260	0.0058	0.2	0.42	0.08	0.536
Otter D	OCD-CCH3-C8	Creek Chub	8	99 - 165	230	0.0098	0.16	0.2	0.025	0.668
Otter D	OCD-CCH4-C14	Creek Chub	14	91 - 142	250	0.0086	0.1	0.2	0.2	0.625

a. In source tables, the value for the length range of this sample was listed as "10-Jun."
g: grams
mm: millimeters
PCBs: polychlorinated biphenyl

Table 4-7. Lines of Evidence for PAHs in Otter Creek/Confluence Sediment[a] Downstream of River Mile 3.4

Location	River Mile	Sampling Program	Date Sampled	Depth (inches)	Midge Biomass[b] (% of Control)	Porewater PAH TU (unitless)	DRO (mg/kg)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)[d]	Total PAH-34[c] (mg/kg)	Total PAH-34[c] (mg/kg at 1% TOC)[z]	ESBTU[d] (unitless)	Field Observations	Fingerprinting Category
Yarrow Street/ Consaul Street	NA	OEPA 2006	10/11/2006	NA	NA	NA	NA	36.9	5.1	NA	NA	NA	NA	NA
OC-12/13	3.35	GLLA 2010-2011	10/15/2010	0-6	89.4	0.4	680	0.6	0.4	1.1	0.7	0.1	NA	Mixed Pyrogenic/Petrogenic
S31-OC-12	3.29	GLNPO 2007	4/3/2007	NA	NA	NA	NA	21.7	4.5	NA	NA	NA	NA	NA
S31-OC-12	3.29	GLNPO 2007	4/3/2007	NA	NA	NA	NA	13.7	2.9	NA	NA	NA	NA	NA
OC-11/12	3.05	GLLA 2010-2011	10/15/2010	0-6	NA	NA	16000	33.2	3.7	262.4	29.4	3.6	odor and sheen	Petrogenic
OC-SED-11	3.00	GLNPO 2007	4/3/2007	NA	NA	NA	NA	28.5	2.4	NA	NA	NA	NA	NA
OC-SED-11	3.00	GLNPO 2007	4/7/2007	NA	NA	NA	NA	33.8	2.8	59.8	5.0	0.6	NA	Pyrogenic
SITE 9	2.97	Envirosafe 2006-2007	8/28/2007	0-6	NA	NA	NA	25.3	6.2	NA	NA	NA	NA	NA
SITE 9	2.97	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	11.5	5.7	23.0	11.5	1.5	NA	NA
OC-10-11	2.90	GLLA 2010-2011	10/7/2010	0-6	NA	NA	1300	1.2	0.3	2.0	0.5	0.1	NA	Pyrogenic
S29-OC-10	2.81	GLNPO 2007	4/4/2007	NA	NA	NA	NA	16.0	0.9	NA	NA	NA	NA	NA
OC-9-10	2.66	GLLA 2010-2011	10/7/2010	0-6	48.9[e]	4.4	2100	1.5	0.3	3.7	0.8	0.1	NA	Mixed Pyrogenic/Petrogenic
SITE 6	2.49	Envirosafe 2006-2007	8/28/2007	0-6	NA	NA	NA	25.7	13.5	NA	NA	NA	NA	NA
SITE 6	2.49	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	2.2	1.1	3.9	1.9	0.2	NA	NA
WLF-SD-02	2.43	WLF 2009	8/20/2009	NA	NA	NA	NA	35.3	17.7	NA	NA	NA	NA	NA
OC-8-9	2.39	GLLA 2010-2011	10/7/2010	0-6	NA	NA	3800	0.9	0.3	5.7	1.9	0.2	NA	Weathered Petrogenic
OC-8	2.29	GLLA 2010-2011	10/12/2010	0-24	NA	NA	8200	2.5[f]	0.7[f]	NA	NA	NA	odor	NA
S27-OC-08	2.29	GLNPO 2007	4/3/2007	NA	NA	NA	NA	9.9	2.0	NA	NA	NA	NA	NA
S27-OC-08	2.29	GLNPO 2007	4/4/2007	NA	NA	NA	NA	107.5	29.0	NA	NA	NA	NA	NA
Millard Road	2.21	OEPA 2006	10/11/2006	NA	NA	NA	NA	20.7	5.3	NA	NA	NA	NA	NA
SITE 4	2.14	Envirosafe 2006-2007	7/17/2006	0-6	NA	NA	NA	4.7	2.4	NA	NA	NA	NA	NA
SITE 4	2.14	Envirosafe 2006-2007	8/28/2007	0-6	NA	NA	NA	23.5	7.6	NA	NA	NA	NA	NA
SITE 4	2.14	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	31.1	15.6	189.1	94.5	13.4	NA	NA
WLF-SD-01	2.14	WLF 2009	8/20/2009	NA	NA	NA	NA	12.3	6.2	NA	NA	NA	NA	NA
OC-7-8	2.14	GLLA 2010-2011	10/7/2010	0-6	NA	NA	1300	1.5	0.5	2.9	0.9	0.1	NA	Mixed Pyrogenic/Petrogenic
SED-T-20A	2.11	Envirosafe 2006-2007	8/29/2007	0-6	NA	NA	NA	3.3[f]	8.0[f]	NA	NA	NA	NA	NA
SED-T-20A	2.11	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	0.3	0.2	2.2	1.1	0.2	NA	NA
SED-T-20	2.11	Envirosafe 2006-2007	8/29/2007	0-6	NA	NA	NA	2.7	2.4	NA	NA	NA	NA	NA
SED-T-20	2.11	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	20.8	10.4	28.8	14.4	1.9	NA	NA
SITE 3	2.10	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	1.4	0.7	5.5	2.8	0.4	NA	NA
OC-SED-07	2.05	GLNPO 2007	4/7/2007	NA	NA	NA	NA	22.2	11.1	98.3	49.1	6.1	NA	Weathered Petrogenic
S26-OC-07	2.05	GLNPO 2007	4/3/2007	NA	NA	NA	NA	11.2	0.8	NA	NA	NA	NA	NA
SITE 1	2.00	Envirosafe 2006-2007	7/17/2006	0-6	NA	NA	NA	22.4	11.2	NA	NA	NA	NA	NA
SITE 1	2.00	Envirosafe 2006-2007	8/28/2007	0-6	NA	NA	NA	10.9	26.5	NA	NA	NA	NA	NA
SITE 1	2.00	Envirosafe 2006-2007	10/15/2007	0-6	NA	NA	NA	6.8	3.4	20.2	10.1	1.5	NA	NA
OC-6/7(2)	1.84	GLLA 2010-2011	10/11/2010	0-24	NA	NA	3000	2.6[f]	0.6[f]	NA	NA	NA	0-12": sheen on water and odor	NA
OC-6/7(2)	1.84	GLLA 2010-2011	10/11/2010	0-6	87.4	4.1	2800	1.4	0.4	6.4	1.6	0.2	NA	Mixed Pyrogenic/Petrogenic
OC-6/7(1)	1.63	GLLA 2010-2011	10/11/2010	0-24	NA	NA	4800	2.6[f]	0.4[f]	NA	NA	NA	odor	NA
OC-6/7(1)	1.63	GLLA 2010-2011	10/11/2010	24-48	NA	NA	9100	2.7[f]	0.9[f]	NA	NA	NA	24-45.5": odor	NA

Table 4-7. Lines of Evidence for PAHs in Otter Creek/Confluence Sediment[a] Downstream of River Mile 3.4

Location	River Mile	Sampling Program	Date Sampled	Depth (inches)	Midge Biomass[b] (% of Control)	Porewater PAH TU (unitless)	DRO (mg/kg)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)[d]	Total PAH-34[c] (mg/kg)	Total PAH-34[c] (mg/kg at 1% TOC)[z]	ESBTU[d] (unitless)	Field Observations	Fingerprinting Category
OC-6/7(1)	1.63	GLLA 2010-2011	10/11/2010	0-6	NA	NA	170	1.7	0.9	5.0	2.6	0.3	odor	Mixed Pyrogenic/Petrogenic
OC-6	1.46	GLLA 2010-2011	10/11/2010	0-24	NA	NA	10000	3.8[f]	0.7[f]	NA	NA	NA	odor	NA
OC-6	1.46	GLLA 2010-2011	10/11/2010	24-48	NA	NA	5800	3.0[f]	0.4[f]	NA	NA	NA	24-41": none	NA
S25-OC-06	1.46	GLNPO 2007	4/2/2007	NA	NA	NA	NA	5.7	0.6	NA	NA	NA	NA	NA
OC-5A	1.25	GLLA 2010-2011	10/8/2010	0-24	NA	NA	5600	3.8[f]	1.6[f]	NA	NA	NA	odor	NA
OC-5A	1.25	GLLA 2010-2011	10/8/2010	24-48	NA	NA	7000	3.2[f]	0.5[f]	NA	NA	NA	24-46": none	NA
OC-5A	1.25	GLLA 2010-2011	10/8/2010	0-6	19.3[e]	6.6	2600	0.5	0.1	2.8	0.9	0.1	NA	Petrogenic
OC-SED-05	1.06	GLNPO 2007	4/2/2007	NA	NA	NA	NA	16.1	1.1	NA	NA	NA	NA	NA
OC-SED-05	1.06	GLNPO 2007	4/7/2007	NA	NA	NA	NA	21.5	1.4	53.9	3.5	0.5	NA	Mixed Pyrogenic/Petrogenic
OC-5	1.06	GLLA 2010-2011	10/8/2010	0-24	NA	NA	8400	3.9	3.5	NA	NA	NA	odor	NA
OC-5	1.06	GLLA 2010-2011	10/8/2010	24-48	NA	NA	27000	5.2	1.2	NA	NA	NA	24-47": none	NA
OC-4A	0.93	GLLA 2010-2011	10/7/2010	0-6	NA	NA	1300	1.2	0.3	2.9	0.9	0.1	NA	Mixed Pyrogenic/Petrogenic
OC-4A	0.93	GLLA 2010-2011	10/7/2010	24-48	NA	NA	5400	4.0	1.0	NA	NA	NA	24-41": odor	NA
OC-4A	0.93	GLLA 2010-2011	10/7/2010	0-24	NA	NA	7600	4.1[f]	1.2[f]	NA	NA	NA	odor	NA
OC-4	0.72	GLLA 2010-2011	10/7/2010	0-6	8.9[e]	18.1	6000	1.1	0.2	8.6	1.7	0.2	NA	Petrogenic
OC-4	0.72	GLLA 2010-2011	10/7/2010	0-24	NA	NA	9500	3.9	1.0	NA	NA	NA	sheen on water and odor	NA
OC-4	0.72	GLLA 2010-2011	10/7/2010	24-48	NA	NA	11000	3.4	0.6	NA	NA	NA	24-42": odor	NA
OC-3A	0.58	GLLA 2010-2011	10/7/2010	0-6	NA	NA	3200	0.4	0.2	4.2	1.9	0.3	NA	Petrogenic
OC-3A	0.58	GLLA 2010-2011	10/7/2010	0-24	NA	NA	15000	4.3	1.1	NA	NA	NA	odor	NA
OC-3A	0.58	GLLA 2010-2011	10/7/2010	24-48	NA	NA	9000	4.2	0.5	NA	NA	NA	24-40": odor; 40-46": none	NA
OC-SED-03	0.44	GLNPO 2007	4/2/2007	NA	NA	NA	NA	12.8	1.2	NA	NA	NA	NA	NA
OC-SED-03	0.44	GLNPO 2007	4/2/2007	NA	NA	NA	NA	10.4	1.0	NA	NA	NA	NA	NA
OC-SED-03	0.44	GLNPO 2007	4/7/2007	NA	NA	NA	NA	34.6	3.2	108.2	9.9	1.2	NA	Weathered Petrogenic
OC-3	0.44	GLLA 2010-2011	10/7/2010	0-24	NA	NA	5100	9.6	1.8	NA	NA	NA	odor	NA
OC-3	0.44	GLLA 2010-2011	10/7/2010	24-48	NA	NA	280	2.7	0.5	NA	NA	NA	24-30": none	NA
OC-2A	0.35	GLLA 2010-2011	10/7/2010	0-6	NA	NA	NA	1.1	0.3	4.3	1.1	0.1	NA	Weathered Petrogenic
OC-2A	0.35	GLLA 2010-2011	10/6/2010	0-24	NA	NA	9900	5.4	1.4	NA	NA	NA	odor	NA
OC-2A	0.35	GLLA 2010-2011	10/6/2010	24-48	NA	NA	NA	8.5	4.3	NA	NA	NA	odor	NA
OC-2A	0.35	GLLA 2010-2011	10/6/2010	48-72	NA	NA	2400	4.5	0.5	NA	NA	NA	48-62": none	NA
OC-2	0.25	GLLA 2010-2011	10/6/2010	0-24	NA	NA	6600	4.4	1.3	NA	NA	NA	odor	NA
OC-2	0.25	GLLA 2010-2011	10/6/2010	24-48	NA	NA	8000	22.5	6.8	NA	NA	NA	24-39": none	NA
S21-OC-02	0.24	GLNPO 2007	4/2/2007	NA	NA	NA	NA	15.8	1.0	NA	NA	NA	NA	NA
OC-1A	0.14	GLLA 2010-2011	10/7/2010	0-6	NA	NA	NA	1.0	0.3	6.3	1.7	0.2	NA	Weathered Petrogenic
OC-1A	0.14	GLLA 2010-2011	10/4/2010	0-12	NA	NA	NA	23.7	11.9	NA	NA	NA	NA	NA
OC-1A	0.14	GLLA 2010-2011	10/4/2010	24-48	NA	NA	NA	16.4	8.2	NA	NA	NA	odor	NA
OC-45	0.09	GLLA 2010-2011	5/10/2011	0-6	77.2[g]	87.2	5500	3.1	0.8	12.5	3.4	0.5	NA	Petrogenic
OC-45	0.09	GLLA 2010-2011	5/10/2011	0-25	NA	NA	15000	48.7	11.0	NA	NA	NA	0-34": odor and sheen	NA
OC-44	0.05	GLLA 2010-2011	5/10/2011	0-6	27.0[h]	61.5	4200	55.6	7.7	396.8	54.8	7.8	NA	Petrogenic

Table 4-7. Lines of Evidence for PAHs in Otter Creek/Confluence Sediment[a] Downstream of River Mile 3.4

Location	River Mile	Sampling Program	Date Sampled	Depth (inches)	Midge Biomass[b] (% of Control)	Porewater PAH TU (unitless)	DRO (mg/kg)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)[d]	Total PAH-34[c] (mg/kg)	Total PAH-34[c] (mg/kg at 1% TOC)[z]	ESBTU[d] (unitless)	Field Observations	Fingerprinting Category
OC-44	0.05	GLLA 2010-2011	5/10/2011	0-27	NA	NA	60000	166.7	16.3	NA	NA	NA	odor and sheen	NA
OC-SED-01	0.03	GLNPO 2007	4/2/2007	NA	NA	NA	NA	8.8	3.9	NA	NA	NA	NA	NA
OC-SED-01	0.03	GLNPO 2007	4/7/2007	NA	NA	NA	NA	14.9	6.7	48.1	21.5	2.7	NA	Weathered Petrogenic
OC-34	0.00	GLLA 2010-2011	5/10/2011	0-6	NA	0.2	120	1.5	1.2	10.5	8.3	1.2	NA	Petrogenic
OC-34	0.00	GLLA 2010-2011	5/10/2011	0-29	NA	NA	8500	12.3	5.8	NA	NA	NA	0-26": odor	NA
OC-26	-0.08	GLLA 2010-2011	11/3/2010	0-6	4.4[h]	27.6	3300	40.7	16.5	263.5	106.7	14.9	NA	Petrogenic
OC-26	-0.08	GLLA 2010-2011	11/3/2010	0-24	NA	NA	2900	5.2	3.0	NA	NA	NA	odor	NA
OC-26	-0.08	GLLA 2010-2011	11/3/2010	24-49	NA	NA	60	1.3	1.6	NA	NA	NA	odor	NA
OC-27	-0.08	GLLA 2010-2011	11/3/2010	0-6	0.0[e]	31.5	11000	8.4	2.4	187.3	54.0	7.2	sheen	Petrogenic
OC-27	-0.08	GLLA 2010-2011	11/3/2010	0-24	NA	NA	700	4.0	2.3	NA	NA	NA	odor	NA
OC-27	-0.08	GLLA 2010-2011	11/3/2010	24-50	NA	NA	61	0.4	0.4	NA	NA	NA	odor	NA
OC-28	-0.11	GLLA 2010-2011	11/3/2010	0-6	39.3[g]	15.7	2900	13.2	2.3	53.4	9.4	1.2	sheen	Weathered Petrogenic
OC-28	-0.11	GLLA 2010-2011	11/3/2010	0-24	NA	NA	7700	18.3	2.2	NA	NA	NA	odor	NA
OC-28	-0.11	GLLA 2010-2011	11/3/2010	24-48	NA	NA	760	2.4	4.4	NA	NA	NA	none	NA
OC-28	-0.11	GLLA 2010-2011	11/3/2010	48-52	NA	NA	45	0.1	0.2	NA	NA	NA	48-62": odor	NA
OC-29	-0.10	GLLA 2010-2011	11/4/2010	0-6	7.7[h]	26.4	6200	31.7	10.4	101.8	33.4	4.3	odor and sheen	Weathered Petrogenic
OC-29	-0.10	GLLA 2010-2011	11/4/2010	0-24	NA	NA	2500	16.7	8.0	NA	NA	NA	odor and sheen	NA
OC-29	-0.10	GLLA 2010-2011	11/4/2010	24-52	NA	NA	110	2.6	2.8	NA	NA	NA	none	NA
OC-30	-0.11	GLLA 2010-2011	11/4/2010	0-6	9.4[h]	10.5	5300	18.2	7.6	100.2	41.9	5.6	odor	Petrogenic
OC-30	-0.11	GLLA 2010-2011	11/4/2010	0-24	NA	NA	910	13.4	9.5	NA	NA	NA	odor	NA
OC-30	-0.11	GLLA 2010-2011	11/4/2010	24-42	NA	NA	41	1.4	2.8	NA	NA	NA	none	NA
OC-31	-0.11	GLLA 2010-2011	11/4/2010	0-6	58.1	0.4	150	1.2	0.7	3.4	1.9	0.3	none	Mixed Pyrogenic/Petrogenic
OC-31	-0.11	GLLA 2010-2011	11/4/2010	0-24	NA	NA	44	1.3	2.4	NA	NA	NA	odor	NA
OC-31	-0.11	GLLA 2010-2011	11/4/2010	24-48	NA	NA	460	12.8	11.7	NA	NA	NA	none	NA
OC-32	-0.14	GLLA 2010-2011	11/4/2010	0-6	NA	7.6	2100	6.2	1.7	24.5	6.7	0.9	odor	Weathered Petrogenic
OC-32	-0.14	GLLA 2010-2011	11/4/2010	0-24	NA	NA	250	23.5	18.2	NA	NA	NA	none	NA
OC-32	-0.14	GLLA 2010-2011	11/4/2010	24-30	NA	NA	26	1.2	2.7	NA	NA	NA	none	NA
OC-33	-0.17	GLLA 2010-2011	11/4/2010	0-6	NA	0.2	230	0.9	0.5	2.1	1.1	0.2	none	Mixed Pyrogenic/Petrogenic
OC-33	-0.17	GLLA 2010-2011	11/4/2010	0-24	NA	NA	250	4.0	2.4	NA	NA	NA	none	NA
OC-33	-0.17	GLLA 2010-2011	11/4/2010	24-39	NA	NA	16.5[f]	1.0[f]	2.1[f]	NA	NA	NA	none	NA
OC-35	-0.03	GLLA 2010-2011	5/12/2011	0-6	80.1[g]	1.8	1200	2.7	0.5	9.8	1.8	0.2	NA	Weathered Petrogenic
OC-35	-0.03	GLLA 2010-2011	5/12/2011	0-24	NA	NA	3500	3.8	1.4	NA	NA	NA	odor and sheen	NA
OC-36	-0.02	GLLA 2010-2011	5/10/2011	0-15	NA	NA	150	0.05	0.04	NA	NA	NA	none	NA
OC-36	-0.02	GLLA 2010-2011	5/10/2011	0-6	NA	0.5	220	0.8	0.2	3.4	0.9	0.1	NA	Weathered Petrogenic
OC-38	-0.04	GLLA 2010-2011	5/11/2011	0-6	68.1[h]	0.2	120	0.2	0.1	1.3	0.6	0.1	NA	Petrogenic
OC-40	-0.07	GLLA 2010-2011	5/11/2011[i]	0-6	104.9	0.2	180	0.4	0.3	1.8	1.3	0.2	NA	Weathered Petrogenic
OC-40	-0.07	GLLA 2010-2011	5/11/2011	0-23	NA	NA	220	1.2	1.4	NA	NA	NA	none	NA
OC-41	-0.06	GLLA 2010-2011	5/10/2011	0-23	NA	NA	160	0.3	0.3	NA	NA	NA	none	NA
OC-41	-0.06	GLLA 2010-2011	5/10/2011	0-6	85.5[g]	0.2	190	0.6	0.6	2.2	2.2	0.3	NA	Weathered Petrogenic
OC-42	-0.05	GLLA 2010-2011	5/11/2011	0-6	1.7[h]	169.8	13000	34.6	7.6	157.3	34.7	4.8	NA	Weathered Petrogenic
OC-42	-0.05	GLLA 2010-2011	5/11/2011	0-23	NA	NA	410	2.6	1.6	NA	NA	NA	0-26": odor and sheen	NA

Table 4-7. Lines of Evidence for PAHs in Otter Creek/Confluence Sediment[a] Downstream of River Mile 3.4

ocation	River Mile	Sampling Program	Date Sampled	Depth (inches)	Midge Biomass[b] (% of Control)	Porewater PAH TU (unitless)	DRO (mg/kg)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)[d]	Total PAH-34[c] (mg/kg)	Total PAH-34[c] (mg/kg at 1% TOC)[z]	ESBTU[d] (unitless)	Field Observations	Fingerprinting Category
OC-46	-0.08	GLLA 2010-2011	5/12/2011	0-6	69.0[h]	0.6	120	0.5	0.2	1.0	0.4	0.1	NA	Mixed Pyrogenic/Petrogenic
OC-46	-0.08	GLLA 2010-2011	5/12/2011	0-24	NA	NA	500	1.8	0.8	NA	NA	NA	none	NA
OC-47	-0.09	GLLA 2010-2011	5/12/2011	0-6	NA	0.3	110	0.8	0.4	1.1	0.5	0.1	NA	Mixed Pyrogenic/Petrogenic
OC-47	-0.09	GLLA 2010-2011	5/12/2011	0-24	NA	NA	81	0.7	0.3	NA	NA	NA	organic odor	NA
OC-47	-0.09	GLLA 2010-2011	5/12/2011	24-48	NA	NA	180	0.8	0.4	NA	NA	NA	none	NA
OC-47	-0.09	GLLA 2010-2011	5/12/2011	48-62	NA	NA	490	1.0	0.5	NA	NA	NA	48-64": none	NA
OC-48	-0.09	GLLA 2010-2011	5/12/2011	0-6	NA	0.3	110	1.4	0.7	2.3	1.1	0.1	NA	Mixed Pyrogenic/Petrogenic
OC-48	-0.09	GLLA 2010-2011	5/12/2011	0-24	NA	NA	160	0.3	0.1	NA	NA	NA	none	NA
OC-48	-0.09	GLLA 2010-2011	5/12/2011	24-48	NA	NA	330	1.7	0.8	NA	NA	NA	none	NA
OC-48	-0.09	GLLA 2010-2011	5/12/2011	48-60	NA	NA	340	1.7	0.7	NA	NA	NA	48-74": none	NA
OC-49	-0.09	GLLA 2010-2011	10/18/2011	0-6	8.4[e]	67.7	NA	3.3	0.9	9.8	2.8	0.4	odor and sheen	Weathered Petrogenic
OC-49	-0.09	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	5.3	3.5	NA	NA	NA	odor and sheen	NA
OC-49	-0.09	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	1.0[f]	1.2[f]	NA	NA	NA	31-58": none	NA
OC-50	-0.09	GLLA 2010-2011	10/18/2011	0-6	10.5[e]	133.6	NA	1.2	0.4	4.7	1.6	0.2	odor and sheen	Weathered Petrogenic
OC-50	-0.09	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	2.1	0.7	NA	NA	NA	odor and sheen	NA
OC-50	-0.09	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	1.0[f]	1.2[f]	NA	NA	NA	odor and sheen	NA
OC-50	-0.09	GLLA 2010-2011	10/18/2011	48-63	NA	NA	NA	1.0[f]	1.0[f]	NA	NA	NA	none	NA
OC-51	-0.14	GLLA 2010-2011	10/18/2011	0-6	66.6[e]	5.2	NA	0.2	0.1	0.5	0.2	0.03	odor	Weathered Petrogenic
OC-51	-0.14	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.1	0.8	NA	NA	NA	odor	NA
OC-51	-0.14	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	1.0[f]	1.6[f]	NA	NA	NA	24-44": none	NA
OC-52	-0.12	GLLA 2010-2011	10/18/2011	0-6	9.3[e]	58.2	NA	0.8	0.1	3.8	0.6	0.1	odor and sheen	Weathered Petrogenic
OC-52	-0.12	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	2.1	0.5	NA	NA	NA	odor	NA
OC-52	-0.12	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	1.9	0.6	NA	NA	NA	none	NA
OC-52	-0.12	GLLA 2010-2011	10/18/2011	48-64	NA	NA	NA	1.0[f]	1.5[f]	NA	NA	NA	none	NA
OC-53	-0.15	GLLA 2010-2011	10/18/2011	0-6	92.0	2.9	NA	0.8	0.4	2.1	1.0	0.1	odor and sheen	Weathered Petrogenic
OC-53	-0.15	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.2[f]	1.0[f]	NA	NA	NA	odor	NA
OC-53	-0.15	GLLA 2010-2011	10/18/2011	24-32	NA	NA	NA	1.1	1.0	NA	NA	NA	none	NA
OC-54	-0.13	GLLA 2010-2011	10/18/2011	0-6	93.9	7.7	NA	1.5	0.5	5.1	1.7	0.2	none	Weathered Petrogenic
OC-54	-0.13	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	2.5	0.7	NA	NA	NA	odor, sheen, and visible oil	NA
OC-54	-0.13	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	45.0	10.5	NA	NA	NA	odor, sheen, and visible oil	NA
OC-54	-0.13	GLLA 2010-2011	10/18/2011	48-65	NA	NA	NA	34.3	8.9	NA	NA	NA	none	NA
OC-55	-0.18	GLLA 2010-2011	10/18/2011	0-6	93.2	1.0	NA	0.2	0.1	0.5	0.2	0.03	none	Weathered Petrogenic
OC-55	-0.18	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.6	1.0	NA	NA	NA	odor	NA
OC-55	-0.18	GLLA 2010-2011	10/18/2011	24-42	NA	NA	NA	1.2[f]	0.4[f]	NA	NA	NA	none	NA
OC-56	-0.16	GLLA 2010-2011	10/18/2011	0-6	91.1	70.7	NA	6.7	1.8	43.9	11.9	1.8	odor and sheen	Petrogenic
OC-56	-0.16	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	3.7	1.0	NA	NA	NA	odor and visible oil	NA
OC-56	-0.16	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	4.0	1.5	NA	NA	NA	odor and visible oil	NA

Table 4-7. Lines of Evidence for PAHs in Otter Creek/Confluence Sediment[a] Downstream of River Mile 3.4

Location	River Mile	Sampling Program	Date Sampled	Depth (inches)	Midge Biomass[b] (% of Control)	Porewater PAH TU (unitless)	DRO (mg/kg)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)[d]	Total PAH-34[c] (mg/kg)	Total PAH-34[c] (mg/kg at 1% TOC)[z]	ESBTU[d] (unitless)	Field Observations	Fingerprinting Category
OC-56	-0.16	GLLA 2010-2011	10/18/2011	48-72	NA	NA	NA	4.3	2.6	NA	NA	NA	odor	NA
OC-56	-0.16	GLLA 2010-2011	10/18/2011	72-96	NA	NA	NA	2.5	0.9	NA	NA	NA	odor	NA
OC-56	-0.16	GLLA 2010-2011	10/18/2011	96-112	NA	NA	NA	1.7	1.1	NA	NA	NA	odor	NA
OC-57	-0.16	GLLA 2010-2011	10/18/2011	0-6	85.1	8.7	NA	3.7	0.8	17.3	4.0	0.5	odor and sheen	Weathered Petrogenic
OC-57	-0.16	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.5	0.5	NA	NA	NA	odor, sheen, and visible oil	NA
OC-57	-0.16	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	15.7	3.3	NA	NA	NA	odor, sheen, and visible oil	NA
OC-57	-0.16	GLLA 2010-2011	10/18/2011	48-72	NA	NA	NA	6.6	1.3	NA	NA	NA	odor, sheen, and visible oil	NA
OC-57	-0.16	GLLA 2010-2011	10/18/2011	72-96	NA	NA	NA	2.4	0.6	NA	NA	NA	odor, sheen, and visible oil	NA
OC-57	-0.16	GLLA 2010-2011	10/18/2011	96-112	NA	NA	NA	5.4	1.7	NA	NA	NA	96-120": odor, sheen, and visible oil	NA
OC-58	-0.20	GLLA 2010-2011	10/18/2011	0-6	94.9	0.4	NA	0.2	0.1	0.4	0.2	0.02	none	Weathered Petrogenic
OC-58	-0.20	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.4[f]	0.5[f]	NA	NA	NA	odor	NA
OC-58	-0.20	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	1.6	0.6	NA	NA	NA	odor	NA
OC-58	-0.20	GLLA 2010-2011	10/18/2011	48-72	NA	NA	NA	1.4[f]	0.4[f]	NA	NA	NA	odor	NA
OC-58	-0.20	GLLA 2010-2011	10/18/2011	72-96	NA	NA	NA	1.4[f]	0.5[f]	NA	NA	NA	odor and sheen	NA
OC-58	-0.20	GLLA 2010-2011	10/18/2011	96-121	NA	NA	NA	1.4[f]	0.5[f]	NA	NA	NA	odor	NA
OC-59	-0.20	GLLA 2010-2011	10/18/2011	0-6	93.0	0.4	NA	0.2	0.1	0.6	0.2	0.03	NA	Weathered Petrogenic
OC-59	-0.20	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.2[f]	0.4[f]	NA	NA	NA	odor	NA
OC-59	-0.20	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	2.8	1.1	NA	NA	NA	odor and sheen	NA
OC-59	-0.20	GLLA 2010-2011	10/18/2011	48-72	NA	NA	NA	4.9	1.5	NA	NA	NA	odor and sheen	NA
OC-59	-0.20	GLLA 2010-2011	10/18/2011	72-96	NA	NA	NA	1.4	0.3	NA	NA	NA	odor and sheen	NA
OC-59	-0.20	GLLA 2010-2011	10/18/2011	96-121	NA	NA	NA	2.0	0.5	NA	NA	NA	odor and sheen	NA
OC-60	-0.19	GLLA 2010-2011	10/18/2011	0-6	96.3	5.7	NA	9.8	1.8	20.6	3.7	0.5	odor and sheen	Mixed Pyrogenic/Petrogenic
OC-60	-0.19	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	3.0	0.7	NA	NA	NA	odor and sheen	NA
OC-60	-0.19	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	15.9	3.2	NA	NA	NA	odor and sheen	NA
OC-60	-0.19	GLLA 2010-2011	10/18/2011	48-72	NA	NA	NA	18.9	3.1	NA	NA	NA	odor and sheen	NA
OC-60	-0.19	GLLA 2010-2011	10/18/2011	72-96	NA	NA	NA	12.5	2.1	NA	NA	NA	odor	NA
OC-60	-0.19	GLLA 2010-2011	10/18/2011	96-121	NA	NA	NA	3.5	0.7	NA	NA	NA	odor	NA
OC-61	-0.24	GLLA 2010-2011	10/18/2011	0-6	104.0	0.4	NA	0.5	0.2	0.7	0.3	0.04	none	Pyrogenic
OC-61	-0.24	GLLA 2010-2011	10/18/2011	0-24	NA	NA	NA	1.6	0.6	NA	NA	NA	odor	NA
OC-61	-0.24	GLLA 2010-2011	10/18/2011	24-48	NA	NA	NA	1.6	0.6	NA	NA	NA	odor	NA
OC-61	-0.24	GLLA 2010-2011	10/18/2011	48-72	NA	NA	NA	1.5	0.5	NA	NA	NA	odor	NA
OC-61	-0.24	GLLA 2010-2011	10/18/2011	72-96	NA	NA	NA	4.3	1.2	NA	NA	NA	odor	NA
OC-61	-0.24	GLLA 2010-2011	10/18/2011	96-122	NA	NA	NA	7.3	1.9	NA	NA	NA	odor	NA

a. Non-detected concentrations are represented as one-half the detection limit. Total PAH and TU values are identified as non-detects if all PAHs in the sample were below detection limits.
b. GLNPO 2007 toxicity test results are excluded due to data quality concerns (see text).
c. 33 PAHs were analyzed in the Envirosafe 2006-2007 sampling event.

Table 4-7. Lines of Evidence for PAHs in Otter Creek/Confluence Sediment[a] Downstream of River Mile 3.4

Location	River Mile	Sampling Program	Date Sampled	Depth (inches)	Midge Biomass[b] (% of Control)	Porewater PAH TU (unitless)	DRO (mg/kg)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)[d]	Total PAH-34[c] (mg/kg)	Total PAH-34[c] (mg/kg at 1% TOC)[z]	ESBTU[d] (unitless)	Field Observations	Fingerprinting Category

d. PAH concentrations are normalized based on sample-specific TOC if available. Otherwise, a conservative default TOC content of 2% is assumed, based on the 20th percentile of measured TOC concentrations.
e. Statistically different from control based on ERDC analysis (Weston did not conduct analysis)
f. Non-detect
g. Statistically different from control based on Weston analysis only
h. Statistically different from control based on ERDC and Weston analyses
i. Location OC-40: porewater PAHs were sampled on 5/10/2011.

DRO: diesel range organics
ESBTU: equilibrium partitioning sediment benchmark toxic units
mg/kg: milligrams per kilogram
NA: not available
PAH: polycyclic aromatic hydrocarbons
TOC: total organic carbon
TU: toxic units

Table 5-1. Summary of Metal Concentrations in Duck Creek Surface Sediment

Chemical	All data		2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	PEC (mg/kg)	Frequency of PEC Exceedance
Aluminum	24	24	NA	NA	NA	2,640	19,700	10,293	NV	NV
Antimony	11	17	NA	NA	NA	1	7	4	NV	NV
Arsenic	42	42	5	140	73	3	80	20	33	48%
Barium	43	43	68	2,152	454	31	241	113	NV	NV
Beryllium	17	21	NA	NA	NA	0.15	2	1	NV	NV
Cadmium	29	40	0.37	16	3	1	3	1	5	5%
Calcium	24	24	NA	NA	NA	13,500	237,000	84,750	NV	NV
Chromium	40	40	16	190	67	7	65	24	111	5%
Cobalt	14	21	NA	NA	NA	3	20	7	NV	NV
Copper	21	21	NA	NA	NA	9	221	44	149	5%
Iron	24	24	NA	NA	NA	5,100	97,600	23,018	NV	NV
Lead	40	40	68	1076	282	13	156	42	128	38%
Magnesium	24	24	NA	NA	NA	3,830	40,300	14,798	NV	NV
Manganese	24	24	NA	NA	NA	102	1,250	507	NV	NV
Mercury	39	43	0.05	7	0.49	0.0027	0.33	0.094	1.1	2%
Nickel	21	21	NA	NA	NA	13	78	37	48.6	24%
Potassium	20	24	NA	NA	NA	986	3,790	1,557	NV	NV
Selenium	25	37	3	30	9	1	27	6	NV	NV
Silver	4	20	NA	NA	NA	0.033	1	1	NV	NV
Sodium	9	24	NA	NA	NA	71	442	602	NV	NV
Strontium	3	3	NA	NA	NA	279	403	326	NV	NV
Thallium	0	16	NA	NA	NA	NA	NA	3	NV	NV
Vanadium	21	21	NA	NA	NA	19	199	64	NV	NV
Zinc	43	43	109	2,278	570	48	783	180	459	28%

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilogram
NA: not analyzed
NV: screening value not available
PEC: probable effect concentration

Table 5-2. Summary of Metal Concentrations in Duck Creek Sediment Cores

Chemical	All data		2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	PEC (mg/kg)	Frequency of PEC Exceedance
Aluminum	52	52	NA	NA	NA	2,990	20,400	11,893	NV	NV
Antimony	14	47	NA	NA	NA	1	2	4	NV	NV
Arsenic	52	52	NA	NA	NA	7	53	16	33	6%
Barium	52	52	NA	NA	NA	35	181	103	NV	NV
Beryllium	47	52	NA	NA	NA	0.15	1	1	NV	NV
Cadmium	45	52	NA	NA	NA	0.20	6	2	5	6%
Calcium	52	52	NA	NA	NA	16,200	214,000	73,021	NV	NV
Chromium	52	52	NA	NA	NA	7	119	38	111	2%
Cobalt	48	52	NA	NA	NA	1	14	7	NV	NV
Copper	52	52	NA	NA	NA	9	81	37	149	0%
Iron	52	52	NA	NA	NA	4,230	30,500	20,346	NV	NV
Lead	52	52	NA	NA	NA	9	158	42	128	2%
Magnesium	52	52	NA	NA	NA	4,550	22,400	10,817	NV	NV
Manganese	52	52	NA	NA	NA	130	1,760	401	NV	NV
Mercury	51	51	NA	NA	NA	0.01	1	0	1.1	2%
Nickel	52	52	NA	NA	NA	10	52	31	48.6	2%
Potassium	52	52	NA	NA	NA	493	6,650	2,158	NV	NV
Selenium	36	48	NA	NA	NA	0.33	10	5	NV	NV
Silver	32	52	NA	NA	NA	0.06	3	1	NV	NV
Sodium	39	52	NA	NA	NA	47	1,980	343	NV	NV
Thallium	4	46	NA	NA	NA	1	2	2	NV	NV
Vanadium	52	52	NA	NA	NA	10	87	30	NV	NV
Zinc	52	52	NA	NA	NA	36	285	143	459	0%

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilgoram
NA: not analyzed
NV: screening value not available
PEC: probable effect concentration

Table 5-3. Summary of Metal Concentrations in Otter Creek Surface Sediment

Chemical	All data		2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	PEC (mg/kg)	Frequency of PEC Exceedance
Aluminum	46	46	NA	NA	NA	3,570	18,100	9,460	NV	NV
Antimony	23	42	NA	NA	NA	0.10	3	3	NV	NV
Arsenic	77	77	7	83	39	4	37	14	33	23%
Barium	73	73	62	385	211	29	247	96	NV	NV
Beryllium	33	42	NA	NA	NA	0.28	1	0.49	NV	NV
Cadmium	61	73	1	3	2	0.37	4	1	5	0%
Calcium	46	46	NA	NA	NA	21,600	295,000	80,502	NV	NV
Chromium	73	73	28	399	159	7	392	73	111	36%
Chromium, Hexavalent	1	2	NA	NA	NA	1	1	1	NV	NV
Cobalt	35	42	NA	NA	NA	5	27	8	NV	NV
Copper	46	46	NA	NA	NA	16	347	73	149	13%
Iron	46	46	NA	NA	NA	6,040	32,800	20,103	NV	NV
Lead	73	73	67	397	215	9	192	65	128	34%
Magnesium	46	46	NA	NA	NA	6,170	65,600	15,268	NV	NV
Manganese	46	46	NA	NA	NA	160	889	419	NV	NV
Mercury	64	73	0.07	1	0.21	0.02	1	0.23	1.1	1%
Nickel	44	46	NA	NA	NA	11	67	27	48.6	4%
Potassium	39	44	NA	NA	NA	629	2,390	1,447	NV	NV
Potassium, Total	2	2	NA	NA	NA	1,000	1,700	1,350	NV	NV
Selenium	25	69	3	4	2	1	10	3	NV	NV
Silver	17	42	NA	NA	NA	0.11	2	1	NV	NV
Sodium	16	46	NA	NA	NA	61	397	474	NV	NV
Strontium	4	4	NA	NA	NA	216	500	307	NV	NV
Thallium	9	38	NA	NA	NA	0.19	2	2	NV	NV
Vanadium	42	42	NA	NA	NA	8	129	24	NV	NV
Zinc	73	73	95	1,042	410	39	440	152	459	12%

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilgoram
NA: not analyzed
NV: screening value not available
PEC: probable effect concentration

Table 5-4. Summary of Metal Concentrations in Otter Creek Sediment Cores

Chemical	All data		2007 GLNPO data			All other data			All data	
	Number of Detects	Number of Samples	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	PEC (mg/kg)	Frequency of PEC Exceedance
Aluminum	60	60	NA	NA	NA	4,460	22,900	9,200	NV	NV
Antimony	29	60	NA	NA	NA	0.32	4	3	NV	NV
Arsenic	60	60	NA	NA	NA	3	56	13	33	3%
Barium	60	60	NA	NA	NA	27	184	95	NV	NV
Beryllium	46	60	NA	NA	NA	0.31	1	0.46	NV	NV
Cadmium	39	60	NA	NA	NA	0.21	2	1	5	0%
Calcium	60	60	NA	NA	NA	7,040	266,000	97,019	NV	NV
Chromium	60	60	NA	NA	NA	10	340	90	111	38%
Cobalt	52	60	NA	NA	NA	4	36	8	NV	NV
Copper	60	60	NA	NA	NA	12	775	77	149	10%
Iron	60	60	NA	NA	NA	11,600	38,700	18,685	NV	NV
Lead	60	60	NA	NA	NA	8	1,080	67	128	7%
Magnesium	60	60	NA	NA	NA	4,080	44,200	12,028	NV	NV
Manganese	60	60	NA	NA	NA	164	3,110	417	NV	NV
Mercury	51	60	NA	NA	NA	0.01	2	0	1.1	2%
Nickel	60	60	NA	NA	NA	15	72	25	48.6	2%
Potassium	52	60	NA	NA	NA	625	3,320	1,361	NV	NV
Selenium	26	52	NA	NA	NA	1	6	3	NV	NV
Silver	18	60	NA	NA	NA	0.10	3	1	NV	NV
Sodium	22	60	NA	NA	NA	36	499	336	NV	NV
Thallium	18	55	NA	NA	NA	1	4	2	NV	NV
Vanadium	60	60	NA	NA	NA	11	38	20	NV	NV
Zinc	60	60	NA	NA	NA	32	213	98	459	0%

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilgoram
NA: not analyzed
NV: screening value not available
PEC: probable effect concentration

Table 5-5. Comparison of 2007 and 2010-2011 Duck and Otter Creeks Sediment Sampling Methodology

Component	Sediment Sampling Methodology	
	GLNPO 2007 (SulTRAC 2007)	GLLA 2010-2011 (Weston 2010a,b)
Sample Depth	Upper 6 to 12 inches of sediment	Upper 3 to 6 inches of sediment
Sample equipment	Ponar or stainless-steel shovels and hand trowels	Petite Ponar or Eckmann dredge
Sampling approach	Started sampling downstream, approached location from downstream	Sampled downstream to upstream
Sample location	Collected from depositional environments, if present	Collected from selected locations, depending on availability of depositional material
Sampling method	Multiple grab samples within an area approximately 5 feet in diameter	Not specified
Removal of foreign materials	Non-sediment material (such as rocks, twigs, or leaves) removed	Not specified
Homogenization	Yes	Yes, AVS/SEM fraction not homogenized prior to collection to avoid sample oxidation
Homogenization container	Ziploc bag, stainless steel bowl, or disposable container	Stainless steel or aluminum pan
Analysis container	Not specified	Clear glass jar
Preservation	Not specified	Chilled to 4°C immediately upon collection

AVS/SEM: acid volatile sulfide/simultaneously extracted metals
CLP: Contract Laboratory Program
CRL: Chicago Regional Laboratory
GLLA: Great Lakes Legacy Act
GLNPO: Great Lakes National Program Office

Table 5-6. Summary of PEC Exceedance Frequency for Metals

Chemical	Otter Creek		Duck Creek	
	Sediment Cores	Surface Sediment	Sediment Cores	Surface Sediment
Arsenic	3%	23%	6%	48%
Cadmium	0%	0%	6%	5%
Chromium	38%	36%	2%	5%
Copper	10%	13%	0%	5%
Lead	7%	34%	2%	38%
Mercury	2%	1%	2%	2%
Nickel	2%	4%	2%	24%
Zinc	0%	12%	0%	28%

PEC: probable effect concentration
Shading indicates frequency of exceedance greater than 10%.

Table 5-7. Analysis of (SEM-AVS)/foc in Duck Creek, Otter Creek, Grassy Creek, and Amlosch Ditch

Location	Date	Metals (µmol/g)	Sulfide (µmol/g)	TOC (%)	(SEM-AVS)/foc (µmol/goc)
Duck Creek					
DC-SED-01	2007	1.29	8.7	11	-67
DC-SED-03	2007	1.02	10.3	7	-133
DC-SED-05	2007	3.41	59.3	36	-156
DC-SED-08	2007	2.14	76.4	35	-213
DC-SED-10	2007	1.03	11.3	13	-76
DC-SED-13	2007	1.91	20.3	9	-205
DC-SED-14	2007	1.21	21.9	30	-69
DC-10/11	2010	1.36	49.6	7	-710
DC-11/12	2010	0.45	8.06	23	-33
DC-13	2010	1.10	8.3	34	-21
DC-14	2010	0.67	7.7	9	-78
DC-16	2010	0.71	6.9	19	-33
DC-17	2010	0.51	1.29	14	-5
DC-19	2010	0.48	7.2	10	-68
DC-3	2010	0.54	13.8	8	-166
DC-3/4	2010	0.97	29.8	5	-606
DC-4	2010	1.61	13.7	6	-196
DC-5	2010	3.78	97	5	-1868
DC-5/6	2010	7.97	209	8	-2405
DC-6/7	2010	5.08	111	8	-1403
DC-7/8	2010	0.85	37.1	6	-576
DC-9/10	2010	1.16	25.6	5	-455
DC-21	2011	1.73	64.6	5	-1262
DC-22	2011	0.42	2.65	7	-31
DC-23	2011	1.53	11.5	14	-72
DC-24	2011	0.64	7.62	16	-44
DC-25	2011	1.84	24.1	9	-238
Otter Creek					
OC-SED-01	2007	1.18	2.5	2	-59
OC-SED-03	2007	3.82	17.6	14	-102
OC-SED-05	2007	3.87	14	15	-67
OC-SED-07	2007	2.78	23.4	14	-144
OC-SED-11	2007	3.55	32.1	12	-239
OC-SED-14	2007	2.98	16.9	4	-368
OC-SED-19	2007	1.73	8.7	2	-389
OC-SED-22	2007	2.96	39	9	-413
OC-SED-26	2007	1.67	7.2	4	-125
OC-10-11	2010	1.63	0.408	4	33
OC-11/12	2010	4.68	77	9	-812
OC-12/13	2010	1.27	13	2	-724
OC-15/16	2010	0.68	0.74	3	-2
OC-16	2010	0.59	2.02	4	-40
OC-16/17	2010	0.89	1.19	3	-10
OC-18/19	2010	1.45	1.03	3	13
OC-1A	2010	1.41	7.2	4	-152
OC-22	2010	1.28	41.6	4	-1064
OC-24/25	2010	0.43	14	2	-780
OC-26	2010	0.69	6.49	2	-235
OC-27	2010	0.78	7.29	3	-188
OC-28	2010	0.45	5.62	6	-91
OC-29	2010	0.66	28.2	3	-903
OC-2A	2010	1.01	19	4	-453
OC-30	2010	0.62	6.09	2	-229
OC-31	2010	0.25	2.62	2	-134

Table 5-7. Analysis of (SEM-AVS)/foc in Duck Creek, Otter Creek, Grassy Creek, and Amlosch Ditch

Location	Date	Metals (µmol/g)	Sulfide (µmol/g)	TOC (%)	(SEM-AVS)/foc (µmol/goc)
OC-32	2010	0.42	1.81	4	-38
OC-33	2010	0.35	1.57	2	-65
OC-3A	2010	1.55	5.4	2	-174
OC-4	2010	1.59	21.3	5	-398
OC-4A	2010	1.62	1.32	3	9
OC-5A	2010	1.86	2.7	3	-27
OC-6/7(1)	2010	0.68	0.45	2	12
OC-6/7(2)	2010	2.39	12.8	4	-266
OC-7-8	2010	1.66	5.5	3	-115
OC-8-9	2010	2.53	6.11	3	-117
OC-9-10	2010	2.61	30.5	5	-596
OC-34	2011	0.08	0.232	1	-12
OC-35	2011	1.10	7.84	5	-126
OC-36	2011	0.21	0.489	4	-7
OC-38	2011	0.13	0.0025	2	6
OC-40	2011	0.12	0.059	1	4
OC-41	2011	0.17	0.003	1	17
OC-42	2011	1.14	7.6	5	-143
OC-44	2011	1.12	7.7	7	-91
OC-45	2011	0.97	6.1	4	-141
OC-46	2011	0.30	2.15	2	-82
OC-47	2011	0.43	0.42	2	1
OC-48	2011	0.65	3.2	2	-127
AD-1	2010	1.14	38.1	5	-729
GC-1	2010	0.77	20.7	2	-940

AVS/SEM: acid volatile sulfide/simultaneously extracted metals
foc: fraction organic carbon
µmol/g: micromol per gram
µmol/goc: micromol per gram organic carbon
TOC: total organic carbon

Table 5-8. Screening of Metal Concentrations in Duck and Otter Creek Porewater

Chemical	Number of Detects	Number of Samples	Minimum Detect (µg/L)	Maximum Detect (µg/L)	Average (µg/L)	OEPA OMZA (µg/L)	Frequency of Exceedence
Antimony	42	42	0.057	1.81	0.4	190	0%
Arsenic	42	42	2.2	62.6	12.3	150	0%
Barium	42	42	15.7	329	73.4	220	5%
Beryllium	12	42	0.004	0.025	0.0052	100	0%
Cadmium	34	42	0.004	0.23	0.047	6.6	0%
Chromium	36	42	0.22	8.56	1.4	230	0%
Cobalt	42	42	0.211	2.86	0.8	24	0%
Copper	42	42	0.25	9.26	2.3	29	0%
Lead	42	42	0.01	9.18	0.4	30	0%
Manganese	42	42	2.95	4,210	1,132	6,521[a]	0%
Mercury	1	42	0.06	0.06	0.024	0.77	0%
Nickel	42	42	1.58	11	4.9	170	0%
Selenium	40	42	0.3	3.7	0.9	4.6	0%
Silver	4	42	0.005	0.008	0.0037	15	0%
Thallium	31	42	0.004	0.111	0.023	17	0%
Vanadium	41	42	0.2	6.66	1.5	44	0%
Zinc	42	42	0.6	13.4	3.2	380	0%

a. Where Ohio Environmental Protection Agency (OEPA) OMZA criteria were not available, Michigan Department of Environmental Quality final chronic values are used. Hardness-dependent WQC are calculated with the average porewater hardness measured in Duck and Otter Creeks (400 mg/L as $CaCO_3$).

OEPA OMZA: Ohio Environmental Protection Agency (2009) Lake Erie Basin Aquatic Life outside mixing zone average water quality criteria

µg/L: micrograms per liter

Table 5-9. Published Spiked Sediment Toxicity Test Results for Arsenic

Species	Chemical Form	Test Media Characteristics	Equilibration Time	Exposure Duration	Effect	Concentration (mg/kg)	Reference
Midge (*Chironomus tentans)*	Arsenic sulfide (form not specified)	Freshwater, sediment = washed sand	Not reported	40 d[a]	Growth & morphology NOEC/LOEC/ EC20[b]	30/130/260	Martinez et al. 2006
Amphipod (*Corophium volutator*)	AsS (realgar)	Estuarine, sediment from mudflats	No equilibrium reached[c]	10 d	LC50	224 - 511	Cui et al. 2011
Amphipod (*Corophium volutator*)	As_2S_3 (orpiment)	Estuarine, sediment from mudflats	No equilibrium reached[c]	10 d	LC50	305 - 592	Cui et al. 2011
Amphipod (*Corophium volutator*)	Fe[AsS] (arsenopyrite)	Estuarine, sediment from mudflats	No equilibrium reached[c]	10 d	LC50	1127 - 1329	Cui et al. 2011
Amphipod (*Hyalella azteca*)	$NaAsO_2$	Freshwater, sediment TOC=7.4%, AVS=1.7 µmol/g	20 d	10 d	LC25/ growth NOEC[d]	521 / 462	Liber et al. 2011
Midge (*Chironomus dilutus*)	$NaAsO_2$	Freshwater, sediment TOC=7.4%, AVS=1.7 µmol/g	20 d	10 d	LC25/ growth IC25[e]	675 / 174	Liber et al. 2011
Mysid (*Americamysis bahia*)	$NaAsO_2$	Marine, sediment TOC=2%, AVS=13 µmol/g	Not reported	7 d	LC50	88.8 mg/kg wet weight[f]	Burgess et al. 2007
Amphipod (*Ampelisca abdita*)	$NaAsO_2$	Marine, sediment TOC=2%, AVS=13 µmol/g	Not reported	7 d	LC50	80.9 mg/kg wet weight[f]	Burgess et al. 2007

a. Multiple exposure durations analyzed in this study. Highest duration of exposure was 50 days. Highest % effect occurred at day 40.

b. EC20 not calculated by authors, but exposure to 260 mg/kg arsenic resulted in 20% larval deformities and a 21% reduction in larval length. The magnitude of effect at the LOEC (12% decrease in larval length, 11% incidence of deformities) was small and may not be ecologically relevant.

c. No steady state thermodynamic equilibrium reached; arsenic minerals were mixed with sediment, and dissolution continued throughout exposure period.

d. NOEC reported instead of IC25 because all *H. azteca* died at next higher As dosage (724 mg/kg).

e. The LOEC for growth was reported as 39 mg/kg, corresponding to an 11% decrease in larval weight (Liber et al. 2011). This magnitude of effect may not be ecologically relevant, because Sibley et al. (1997) demonstrated a threshold for reproductive and population effects in this species corresponding to a 25% decrease in larval weight.

f. Assuming sediment solids content ranging from 30% to 70%, reported wet weight LC50s would be equivalent to 127 to 296 mg/kg dry weight for *A. bahia* and 116 to 270 mg/kg dry weight for *A. abdita*.

d: days

ECX: X% effect concentration

ICX: X% inhibition concentration

LCX: X% lethal concentration

LOEC: lowest observed effect concentration

mg/kg: milligrams per kilogram

NOEC: no observed effect concentration

TOC: total organic carbon

Table 5-10. Benthic Invertebrate Arsenic Toxicity Thresholds for Arsenic-Dominated Sediment Sites

Site	Co-Contaminants	Biological Endpoint	Effect	Arsenic Concentration (mg/kg)	Reference
Wood-treating facility, River Pielishoki, Finland	Copper, chromium	Midge (*Chironomus riparius*) 10-d growth, 50-d emergence	No effect	183	Petänen et al. 2003
Realgar mine, Bravona River, Corsica	Antimony	Benthic community composition	Taxa richness and % Ephemeroptera decreased	354	Mori et al. 1999
			Taxa richness not affected; % Ephemeroptera slightly decreased	207	
			No effect	95	
Elastomers plant, Davis Creek, Ohio	Not reported	Amphipod (*Hyalella azteca*) and Midge (*Chironomus tentans*), 10-d survival, growth; benthic macorinvertebarate community status	No effect	339	Huddleston et al. 2009

mg/kg: milligrams per kilogram

Table 5-11. Published Spiked Sediment Toxicity Test Results for Chromium

Species	Chemical Form	Test Media Characteristics	Equilibration Time	Exposure Duration	Effect	Total Chromium (mg/kg)	Post-Spiking AVS (µmol/g)	Reference
Amphipod (*Hyalella azteca*)	Hexavalent ($K_2Cr_2O_7$)	wetted soil TOC=0.82%, AVS=<0.01 µmol/g	1 week	28 days	Survival NOEC, growth and reproduction unbounded NOEC/LC100	36/172	<0.01	Besser et al. 2004
Amphipod (*Hyalella azteca*)	Hexavalent ($K_2Cr_2O_7$)	wetland sediment TOC=2.2%, AVS=55 µmol/g	1 week	28 days	Survival, growth, and reproduction NOEC[b]	4,888	35/11	Besser et al. 2004
Amphipod (*Hyalella azteca*)	Hexavalent ($K_2Cr_2O_7$)	lake sediment TOC=9.0%, AVS=33 µmol/g	1 week	28 days	Survival NOEC, growth and reproduction unbounded NOEC/LC100	4,004/11,440	13/2.6	Besser et al. 2004
Amphipod (*Ampelisca abdita*)	Hexavalent ($K_2Cr_2O_7$)	estuarine muddy surficial sediment, TOC=1.6% dw, AVS=6.6 µmol/g dw	10 days	10 days	Survival NOEC/LOEC	719/1341	1.5/0.6	Berry et al. 2004
Amphipod (*Ampelisca abdita*)	Hexavalent ($K_2Cr_2O_7$)	sandy surficial sediment from coastal salt pond, TOC=0.13% dw, AVS=1.1 µmol/g dw	10 days	10 days	Survival NOEC/LOEC	110/175	0.6/0.01	Berry et al. 2004
Amphipod (*Hyalella azteca*)	Trivalent ($CrCl_3$)	wetted soil TOC=0.82%, AVS=<0.01 µmol/g	1 week	28 days	Survival and reproduction unbounded NOEC, growth unbounded LOEC[a]	1631	<0.01	Besser et al. 2004
Amphipod (*Hyalella azteca*)	Trivalent ($CrCl_3$)	wetland sediment TOC=2.2%, AVS=55 µmol/g	1 week	28 days	Survival and reproduction unbounded NOEC, growth unbounded LOEC[a]	18,200	83	Besser et al. 2004
Amphipod (*Hyalella azteca*)	Trivalent ($CrCl_3$)	lake sediment TOC=9.0%, AVS=33 µmol/g	1 week	28 days	Survival unbounded NOEC, growth and reproduction unbounded LOEC	17,680	6.9/9.4	Besser et al. 2004
Amphipod (*Ampelisca abdita*)	Trivalent ($CrCl_3$)	estuarine muddy surficial sediment, TOC=1.6% dw, AVS=6.6 µmol/g dw	10 days	10 days	Survival unbounded NOEC	20,771	5.3	Berry et al. 2004

a. A 9% reduction in amphipod length at that exposure was statistically significant but is potentially not ecologically significant
b. Although not statistically significant, a 21% reduction in survival and 40% reduction in reproduction was observed.
c. An 8% reduction in amphipod length at that exposure was statistically significant but is potentially not ecologically significant
AVS: acid-volatile sulfides
dw: dry weight
LCX: X% lethal concentration
LOEC: lowest observed effect concentration
NOEC: no observed effect concentration
mg/kg: milligrams per kilogram
µmol/g: micromoles per gram
TOC: total organic carbon

Table 5-12. Benthic Invertebrate Chromium Toxicity Thresholds from Chromium-Dominated Sediment Sites

Site	Co-Contaminants	Biological Endpoint	Effect	Total Chromium (mg/kg)	AVS (µmol/g)	Reference
Shipyard Creek, Charleston, SC	lead, nickel, zinc	Amphipod (*Ampelisca abdita*), 10-d survival	unbounded NOEC[a]	3070	87	Berry et al. 2004
Tannery Bay, Sault Ste. Marie, Michigan	arsenic, cadmium, copper, lead, mercury, nickel, zinc	Amphipod (*Hyalella azteca*), 28-d survival	unbounded NOEC	18430	12.73	Cannelton Industries Incorporated 1994
Hackensack River, New Jersey USA	lead, nickel, mercury, zinc, PAHs, PCBs	Amphipod (*Leptocheirus plumulosus*), 28-d weight[b]	NOEC/LOEC	2780/3970	17/22	Becker et al. 2006
		Amphipod (*Ampelisca abdita*), 10-d survival	NOEC/LOEC	1490/2780	14/17	

a. Statistics are not provided; in all samples, survival was greater than 80%.
b. Significantly reduced survival was observed at 1,490 mg/kg total chromium, but not at higher concentrations.
ECX: X% effect concentration
LCX: X% lethal concentration
mg/kg: milligrams per kilogram
µmol/g: micromoles per gram

Table 5-13. Published Spiked Sediment Toxicity Test Results for Lead

Species	Chemical Form	Test Media Characteristics	Equilibration Time	Exposure Duration	Effect	Concentration (mg/kg dry wt)	Reference
Amphipod (*Hyalella azteca*)	$PbCl_2$	Freshwater, sediment TOC=3%	Not reported	4 weeks	LC25/EC25	3,700 / 6,200	Borgmann and Norwood 1999
Polychaete *(Capitella capitata)*	$Pb(NO_3)_2$	Marine, sediment TOC=9.73%, AVS=50.54 µmol/g	Not reported. Spiked-sediment seawater slurry continuously mixed for 12-126 hr.	10 days	Survival NOEC / LOEC	6,600 / 14,700	Casas and Crecelius 1994
Amphipod *(Melita plumulosa)*	Not specified	Estuarine, sediment TOC=2.2%, AVS=0.6 umol/g	7 to 14 weeks	13 days	Unbounded NOEC (fecundity index)	300	Mann et al. 2009
Amphipod *(Melita plumulosa)*	Not specified	Marine, sediment TOC=14% wet weight	15–40 days until porewater concentrations were low and stable	10 days	Survival NOEC, unbounded growth LOEC	580	King et al. 2006
Midge (*Chironomus tentans*)	PbS	Freshwater, sediment = playground sand	Not reported	50 days	EC8/EC4/EC7 (mouthpart deformity)	1,723 / 3,743 / 5,252	Martinez et al. 2001
Midge (*Chironomus tentans*)	PbS	Freshwater, sediment = playground sand	Not reported	2 generations	Growth NOEC, mouthpart deformity LOEC (6% to 9% affected)	1,442	Martinez et al. 2004
Amphipod (*Elasmopus laevis*)	$Pb(C_2H_3O_2)_2$	Marine water adjusted to estuarine salinity (28 g/L), sediment	25 days	2 generations	Reproduction NOEC / LOEC	118 / 234	Ringenary et al. 2007
Amphipod (*Leptocheirus plumulosus*)	$PbCl_2$	Estuarine, sediment (TOC = 0.64%, 71% fines, and 29% sand)	2 weeks	10 days	Survival NOEC / LC50	795 / 3,969	Stanley et al. 2010
Field colonization of spiked sediment	$Pb(NO_3)_2$	Estuarine, field study in mudflat	2 weeks	10 days	Unbounded NOEC (species richness, abundance, community composition)	85 mg/kg	Fukunaga et al. 2010

AVS: acid-volatile sulfides
ECX: X% effect concentration
fecundity: offspring-per-chamber and/or percent reproductive success
fecundity index: number of embryos multiplied by the stage of development (stages 1-5)
g/L: grams per liter
LCX: X% lethal concentration
LOEC: lowest observed effect concentration
mg/kg: milligrams per kilogram
µmol/g: micromoles per gram
NOEC: no observed effect concentration

Table 5-14. Benthic Invertebrate Lead Toxicity Thresholds from Lead-Dominated Sediment Sites

Site	Co-Contaminants	Biological Endpoint	Effect	Concentration (mg/kg)	Reference
Upper Clark Fork River (Montana)	arsenic, copper, cadmium, manganese, zinc	Amphipod (*Hyalella azteca*) 28-day growth and maturation	NOEC/LOEC	62.4/569	Kemble et al. 1994
Belledune Harbor (New Brunswick, Canada)	cadmium, zinc	Amphipod (*Ampelisca abdita)* 10-day survival	No effect	1140	Hansen et al. 1996
Lakes near Sudbury, Ontario	cadmium, copper, nickel, zinc	Amphipod (*H. azteca*) 28-day survival	LC25	>1170	Borgmann 2003

LC25: 25% lethal concentration
LOEC: lowest observed effect concentration
mg/kg: milligrams per kilogram
NOEC: no observed effect concentration

Table 6-1. Summary and Screening of Total PCB Concentrations in Duck and Otter Creek Sediment

Stream	Sample Type	All data		2007 GLNPO data			All other data			All data	
		Number of Detects	Number of Samples	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	Minimum Detect (mg/kg)	Maximum Detect (mg/kg)	Average (mg/kg)	PEC (mg/kg)	Frequency of Exceedance
Duck	Surface	16	43	0.11	0.49	0.20	0.05	0.27	0.07	0.676	0%
Otter	Surface	52	78	0.06	11.30	0.72	0.02	2.01	0.18	0.676	3%
Duck	Core	35	52	NA	NA	NA	0.02	6.50	1.09	0.676	35%
Otter	Core	36	60	NA	NA	NA	0.01	0.89	0.16	0.676	3%

GLNPO: Great Lakes National Program Office
mg/kg: milligrams per kilogram
NA: not analyzed
PCB: polychlorinated biphenyl
PEC: probable effects concentration

Table 7-1. Summary and Screening of Other Chemicals in Duck and Otter Creek Sediment

Chemical	All Data						TOC-Normalized Results[a]		Screening			
	Number of Detects	Number of Samples	Minimum Detect	Maximum Detect	Average	Units	Maximum Detect	Units	Screening Value	Units	Source	Frequency of Exceedance
Pyrethroid Pesticides												
Bifenthrin	7	12	0.0007	0.007	0.002	mg/kg	0.2	µg/gOC	0.52	µg/gOC	DGI	0%
L-Cyhalothrin	1	12	0.003	0.003	0.001	mg/kg	0.06	µg/gOC	0.45	µg/gOC	DGI	0%
Permethrin	1	12	0.02	0.02	0.008	mg/kg	0.5	µg/gOC	11	µg/gOC	DGI	0%
Organochlorine Pesticides												
Alpha-Chlordane	1	51	0.002	0.002	0.004	mg/kg	0.1	µg/gOC	0.018	mg/kg	PEC	0%
Beta-BHC	1	51	0.001	0.001	0.004	mg/kg	0.06	µg/gOC	0.0050	mg/kg	PEC	0%
DDT, Total	51	55	0.008	0.6	0.08	mg/kg	2.7	ug/gOC	0.57	mg/kg	PEC	4%
Gamma-Chlordane	7	54	0.003	0.02	0.01	mg/kg	0.6	µg/gOC	0.018	mg/kg	PEC	4%
Heptachlor	1	51	0.004	0.004	0.004	mg/kg	0.06	µg/gOC	0.016	mg/kg	PEC	0%
Heptachlor Epoxide	4	51	0.008	0.01	0.004	mg/kg	0.1	µg/gOC	0.016	mg/kg	PEC	0%
Semivolatile Organic Compounds												
1,1-Biphenyl	2	222	0.17	0.55	0.4	mg/kg	26	µg/gOC	18	µg/gOC	EqP (b)	0%
2,4-Dimethylphenol	1	237	0.05	0.05	0.6	mg/kg	1.9	µg/gOC	3.470	µg/gOC	EqP (b)	0%
3-Methylphenol	1	9	0.08	0.08	1.4	mg/kg	4.1	µg/gOC	9.3	µg/gOC	EqP (b)	0%
4-Methylphenol	58	237	0.06	5.7	0.5	mg/kg	137	µg/gOC	7.8	µg/gOC	EqP (b,c)	10%
Acetophenone	39	235	0.08	0.75	0.4	mg/kg	36	µg/gOC	98	µg/gOC	DGI	0%
Benzaldehyde	55	221	0.1	0.53	0.4	mg/kg	20	µg/gOC	457	µg/gOC	DGI	0%
Benzyl Butyl Phthalate	2	235	0.6	1.05	0.4	mg/kg	53	µg/gOC	121	µg/gOC	DGI	0%
Bis(2-	104	240	0.06	31	1.0	mg/kg	703	µg/gOC	732	µg/gOC	DGI	0%
Carbazole	6	222	0.1	0.86	0.5	mg/kg	26	µg/gOC	19	µg/gOC	DGI	0%
Dibenzofuran	11	236	0.08	1.5	0.4	mg/kg	75	µg/gOC	15	µg/gOC	EqP (b)	1%
Diethyl Phthalate	4	236	0.3	0.58	0.4	mg/kg	29	µg/gOC	15	µg/gOC	DGI	0%
Di-N-Butylphthalate	11	235	0.05	0.83	0.6	mg/kg	51	µg/gOC	11	µg/gOC	EqP (d)	1%
Nitrobenzene	2	237	0.8	1.1	0.5	mg/kg	33	µg/gOC	56	µg/gOC	EqP (b)	0%
N-Nitrosodiphenylamine	2	229	0.6	2.2	0.5	mg/kg	50	µg/gOC	24	µg/gOC	EqP (c,e)	0%
Phenol	17	236	0.05	0.4	0.6	mg/kg	6.2	µg/gOC	32	µg/gOC	DGI	0%
Volatile Organic Compounds												
2-Butanone	3	4	0.005	0.01	0.01	mg/kg	0.6	µg/gOC	99	µg/gOC	EqP (b)	0%
Acetone	2	4	0.03	0.1	0.05	mg/kg	5.0	µg/gOC	5	µg/gOC	EqP (c,d)	0%
Carbon Disulfide	4	4	0.001	0.004	0.003	mg/kg	0.2	µg/gOC	0.33	µg/gOC	EqP (b)	0%
Cyclohexane	1	2	0.002	0.002	0.02	mg/kg	0.09	µg/gOC	NV	NV	NV	NV
Methylcyclohexane	1	2	0.003	0.003	0.02	mg/kg	0.1	µg/gOC	NV	NV	NV	NV

Table 7-1. Summary and Screening of Other Chemicals in Duck and Otter Creek Sediment

Chemical	All Data						TOC-Normalized Results[a]		Screening			
	Number of Detects	Number of Samples	Minimum Detect	Maximum Detect	Average	Units	Maximum Detect	Units	Screening Value	Units	Source	Frequency of Exceedance
Toluene	1	4	0.0006	0.0006	0.01	mg/kg	0.03	µg/gOC	15	µg/gOC	EqP (b)	0%

a. For samples without corresponding sediment TOC results, a sediment TOC of 2% (20th percentile of all sediment TOC results) was assumed for TOC normalization
b. Equilibrium partitioning, using Ohio Outside Mixing Zone Average (Lake Erie Basin Aquatic Life Criteria) as water quality value
c. Equilibrium partitioning equation modified for low Koc (Fuchsman 2003); see text
d. Equilibrium partitioning, using Michigan Final Chronic Value as water quality value
e. Equilibrium partitioning, using USEPA Region 5 Ecological Screening Level as water quality value
DGI: Data Gap Investigation Report (Cardno Entrix 2012)
EqP: equilibrium partitioning benchmark
Koc: soil/water organic carbon partition coefficient
mg/kg: milligrams per kilogram
NV: screening value not available
PEC: probable effects concentration (MacDonald et al. 2000)
TOC: total organic carbon
µg/gOC: micrograms per gram organic carbon

Figures

ENVIRON

Sediment Sample Locations
Duck and Otter Creeks

Figure
2-1

Date: 10/25/2012

Document Path: M:\DuckandOtterCreek\GIS\MXD\2-1 Sample Map.mxd

Coordinates Unavailable, sampling location estimated

Sampling location confirmed

0 0.5 1 Miles

N W E S

Duck Creek A

Otter Creek A

Duck Creek

Otter Creek

Otter Creek C

Duck Creek D

Duck Creek E

Otter Creek D

Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

ENVIRON

Fish Tissue Sampling Zones, 2010 Duck and Otter Creeks

Figure 2-2

Date: 10/25/2012

Document Path: M:\DuckandOtterCreek\GIS\MXD\2-2 Fish Tissue.mxd

Otter Creek Confluence

Duck Creek Confluence

See Insets

Duck Creek

Otter Creek

Millard Ave

0 0.5 1 Kilometers

N

W E

S

Statistical Comparison

- Statistically Different
- Statistically Different (Weston Only)
- Not Statistically Different

Magnitude of Effect

- Biomass > 75% of Control
- Biomass 50-75% of Control
- Biomass < 50% of Control

Imagery Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

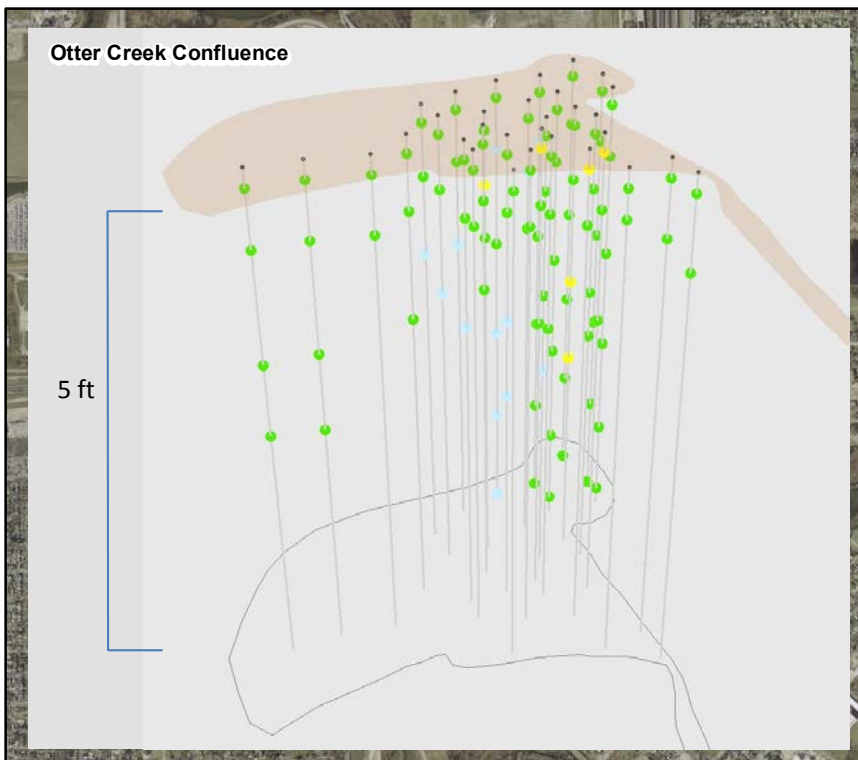
ENVIRON

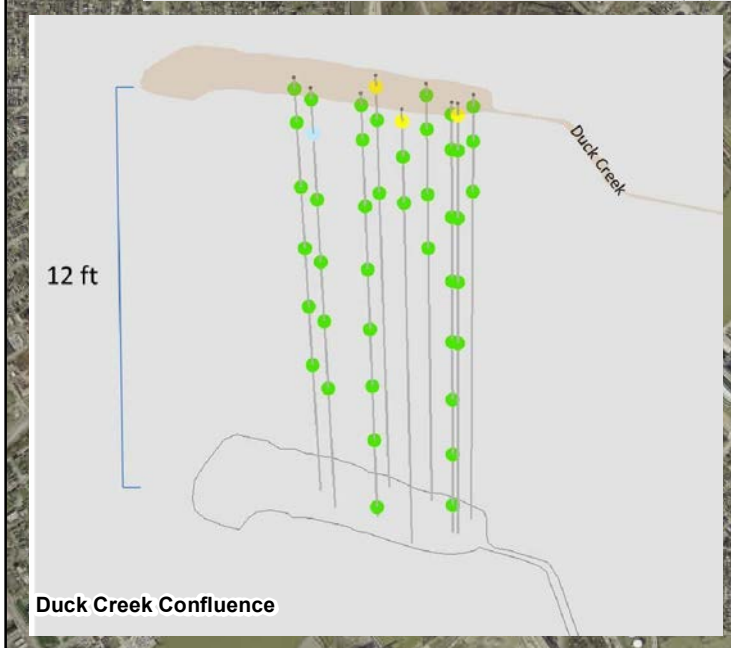
Map of Sediment Toxicity Test Results

Figure 3-1

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\3-1 Sed Tox.mxd





See Insets

Otter Creek

Duck Creek

Millard Ave

Screening
- Non-Detect
- < PEC (22.8 mg/kg)
- < PEC x 2 (45.6 mg/kg)
- > PEC x 2 (45/6 mg/kg)

Depth Range (inches)
- Surface
- 0 - 24
- 24 - 48
- 48 - 72

0 0.5 1 Kilometers

N W E S

Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

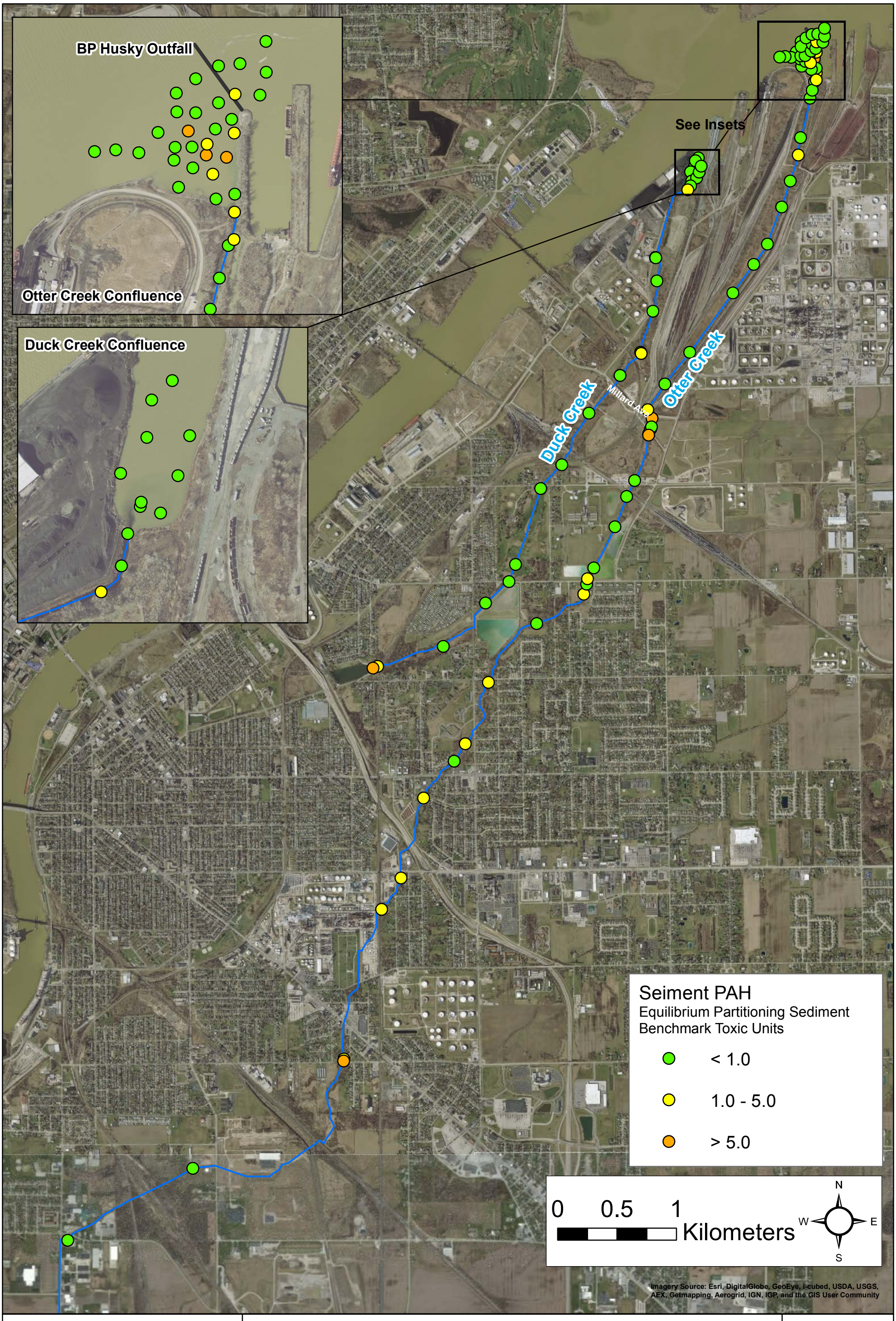
ENVIRON

Map of Sediment Screening Results Total PAH-16

Figure 4-1

Date: 1/22/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\4-1 PAH Screen.mxd



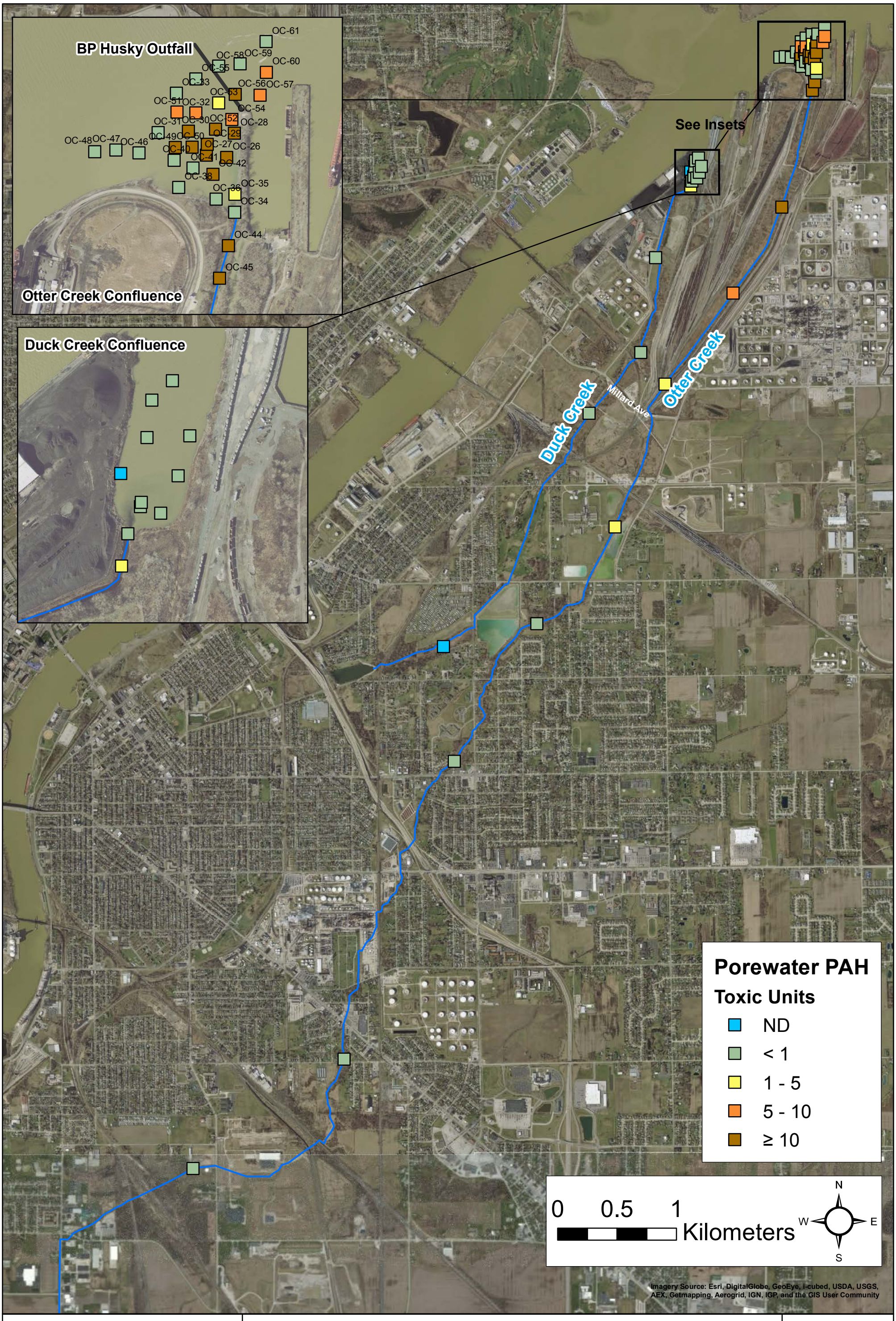
ENVIRON

Map of Bulk Sediment PAH Toxic Units

Figure 4-2

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\4-2 ESBTU.mxd



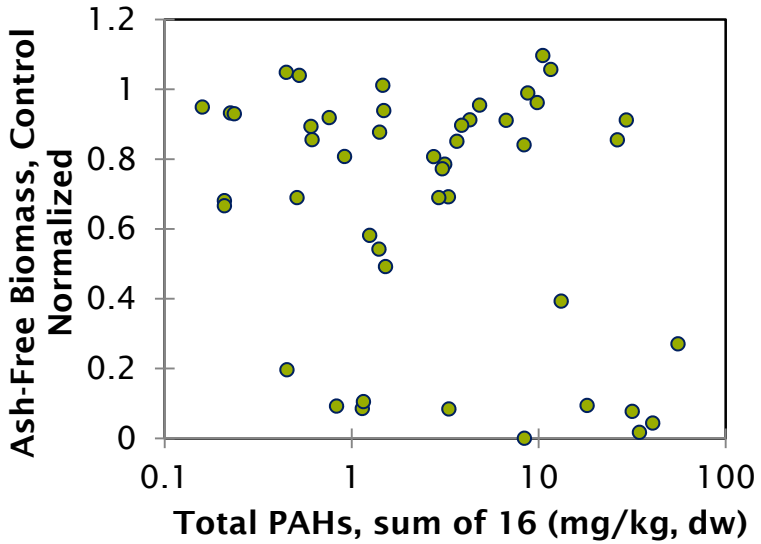
ENVIRON

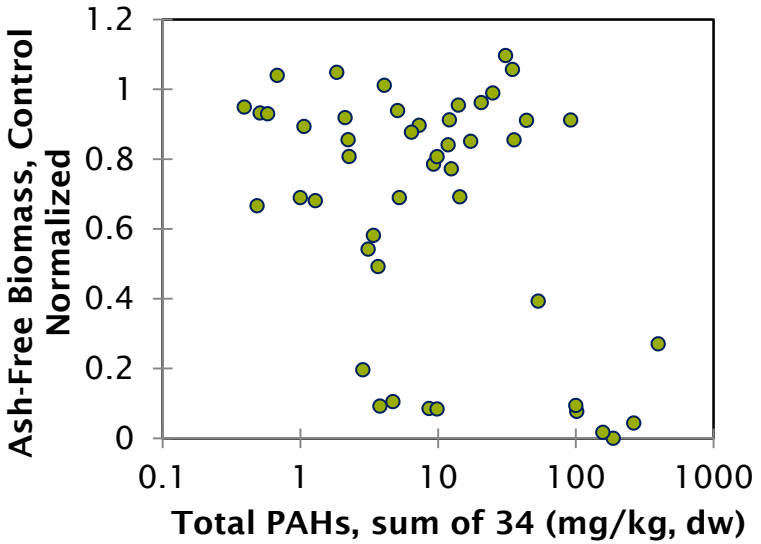
Map of Porewater PAH Toxic Units

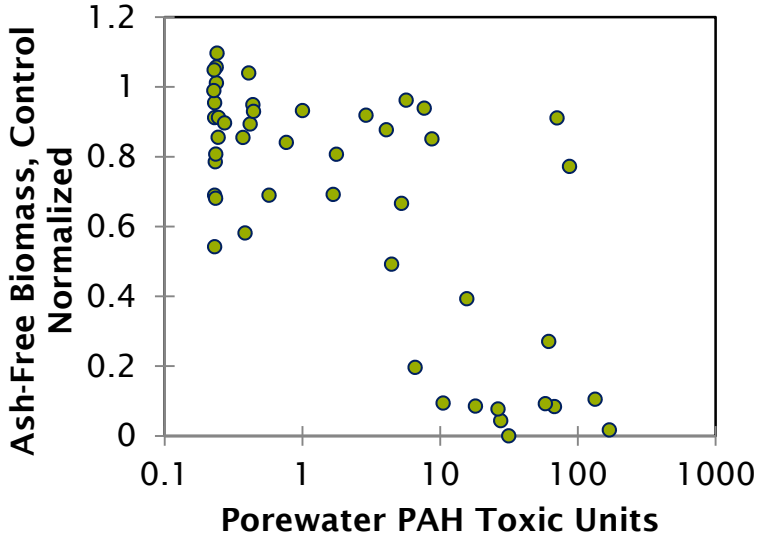
Figure 4-3

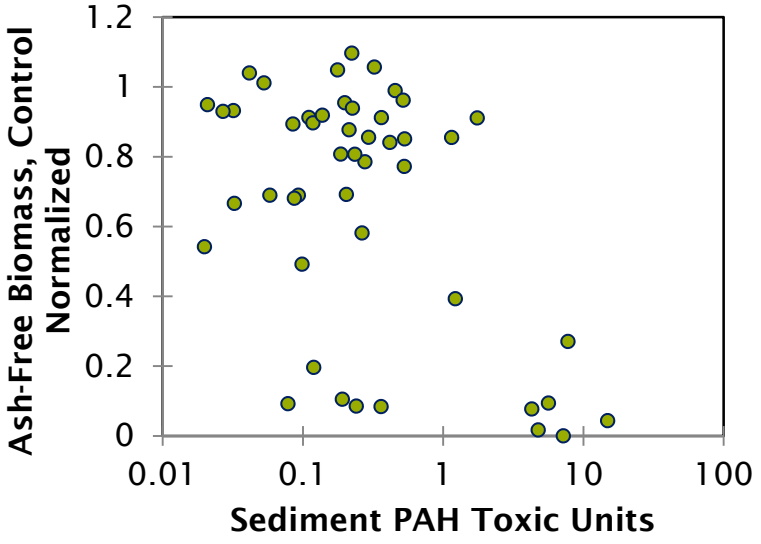
Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\4-3 Porewater PAH TU.mxd





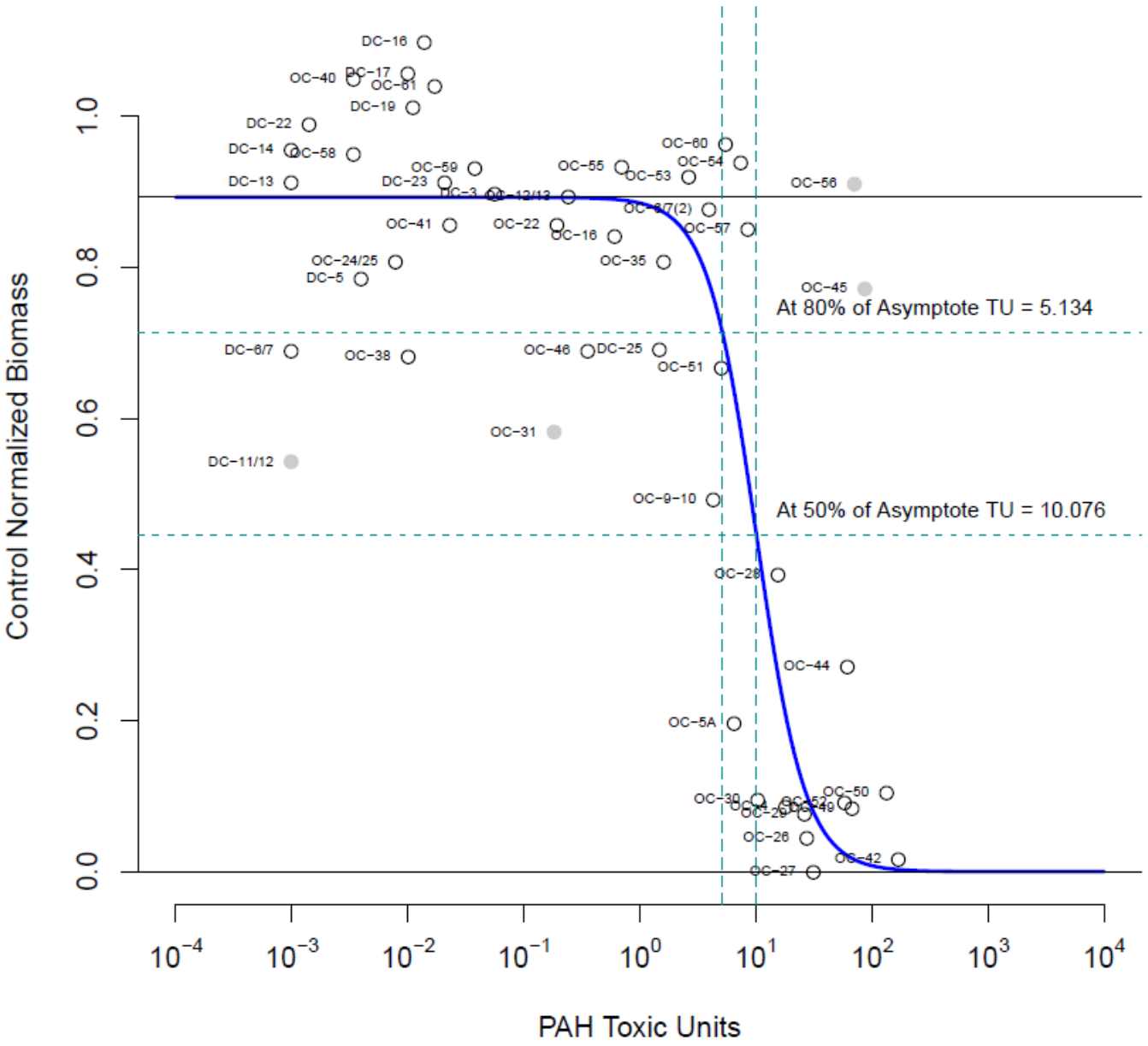




ENVIRON

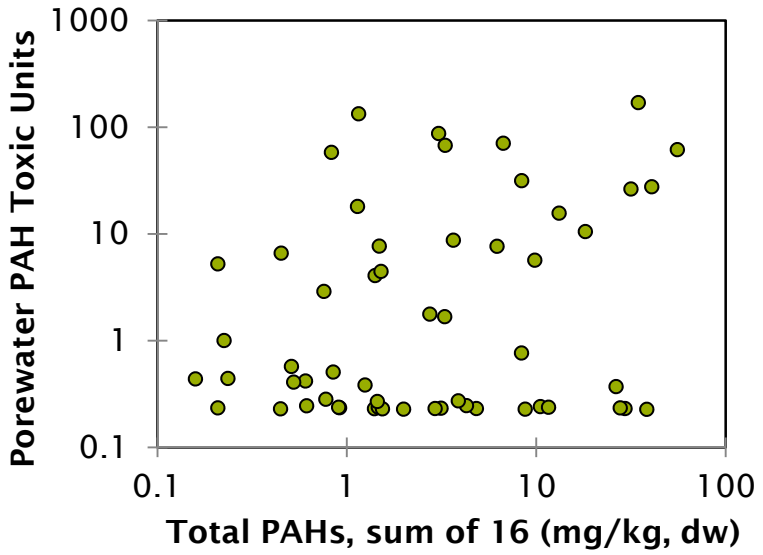
Comparison of Selected Measures of PAH Exposure versus Toxicity Test Results

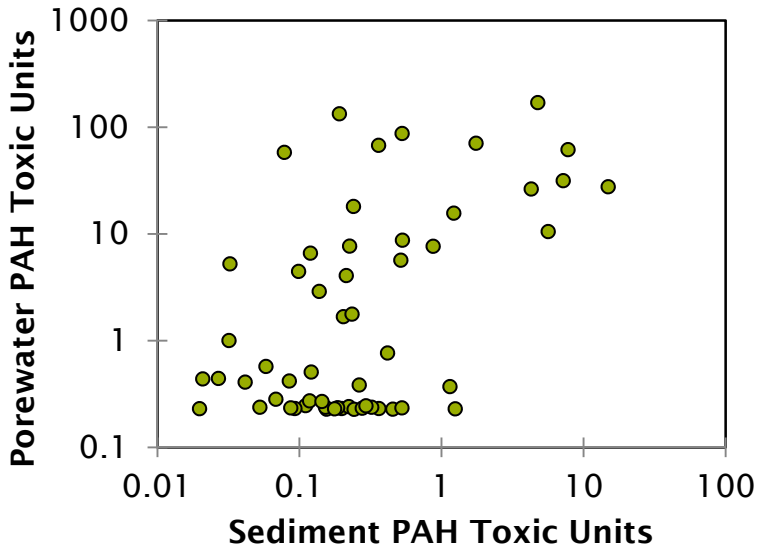
Figure 4-4

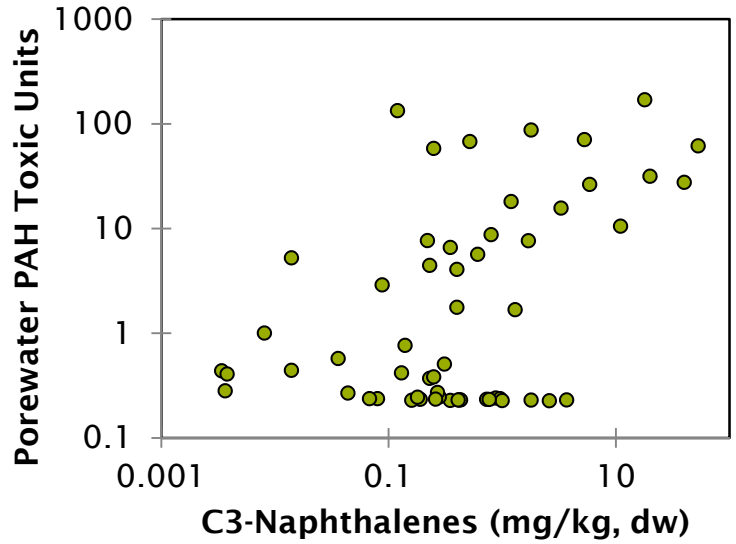


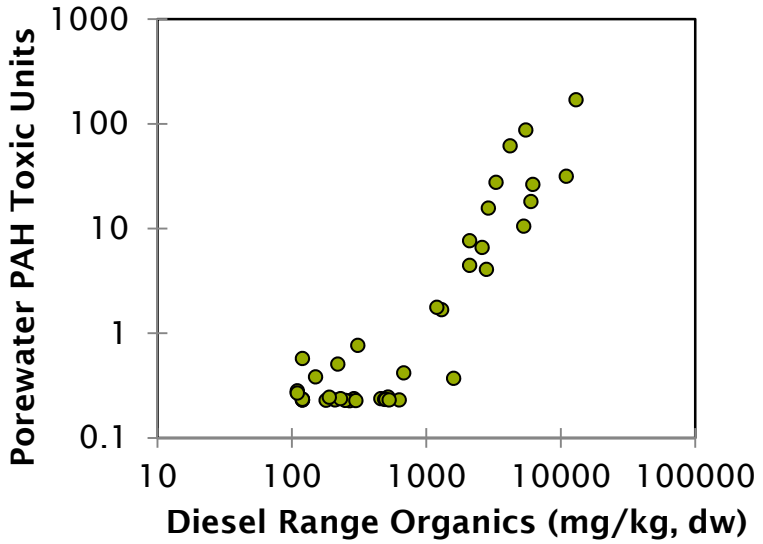
Note: Gray shading indicates outliers not included in curve fit.

ENVIRON	Quantitative Exposure-Response Relationship for Porewater PAH Effects on Midge Biomass	Figure 4-5





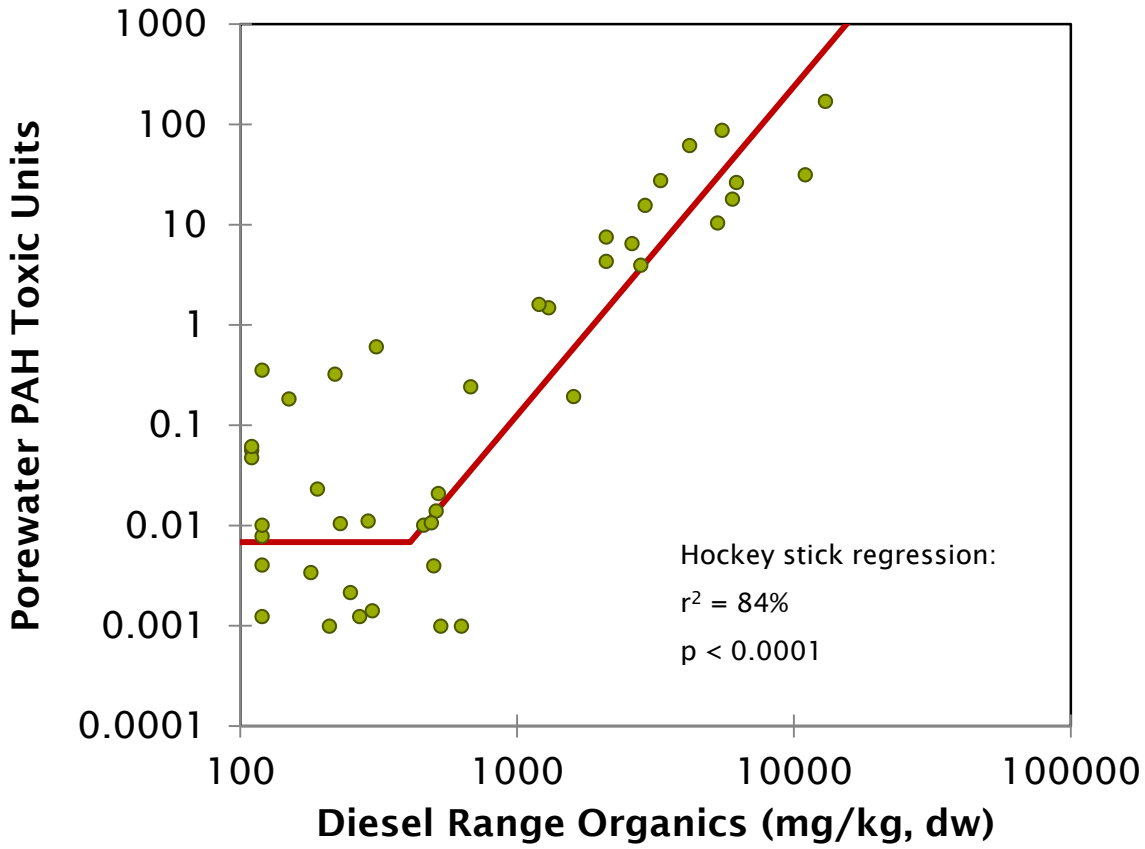




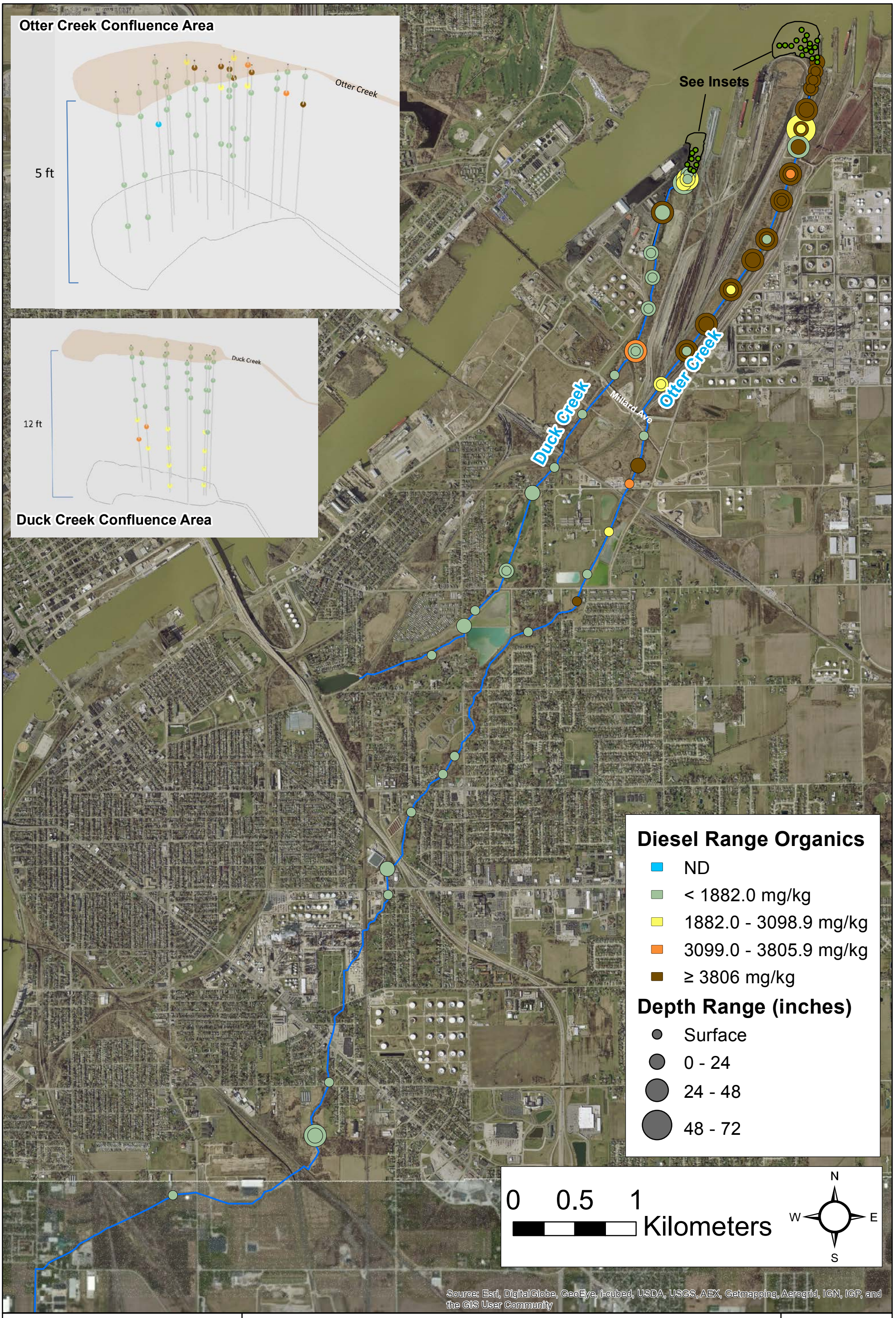
ENVIRON

Comparison of Selected Bulk Sediment Parameters versus Porewater PAH Toxic Units

Figure 4-6



ENVIRON	Quantitative Relationship between DRO Concentrations and Porewater PAH Toxic Units	Figure 4-7



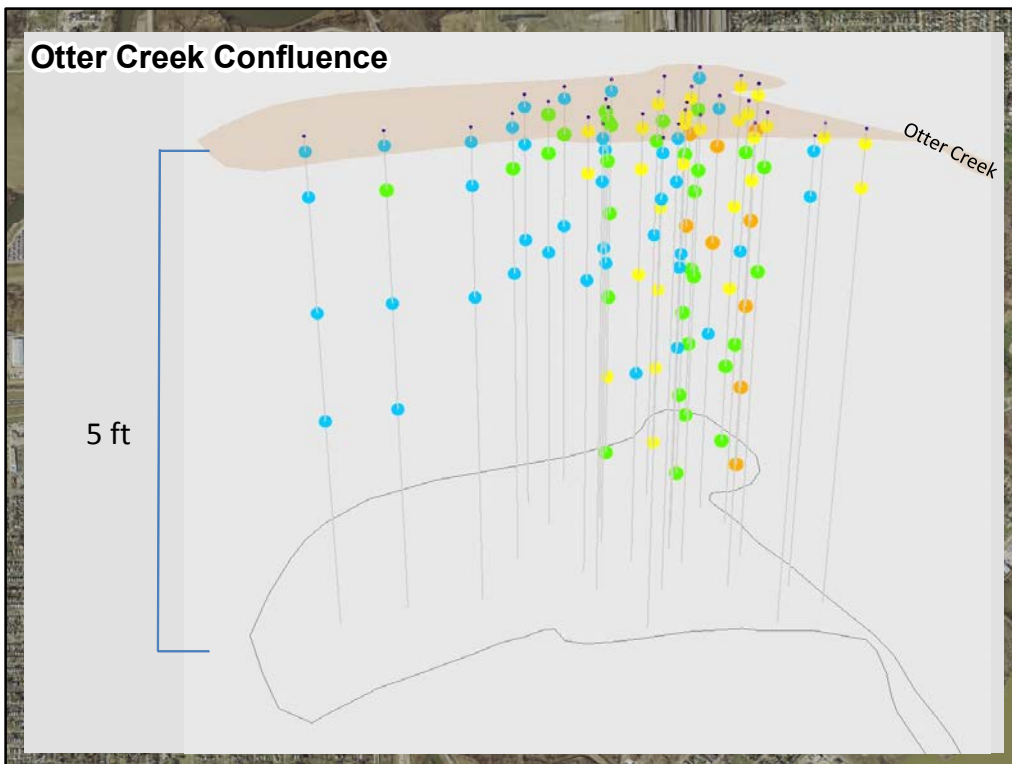
ENVIRON

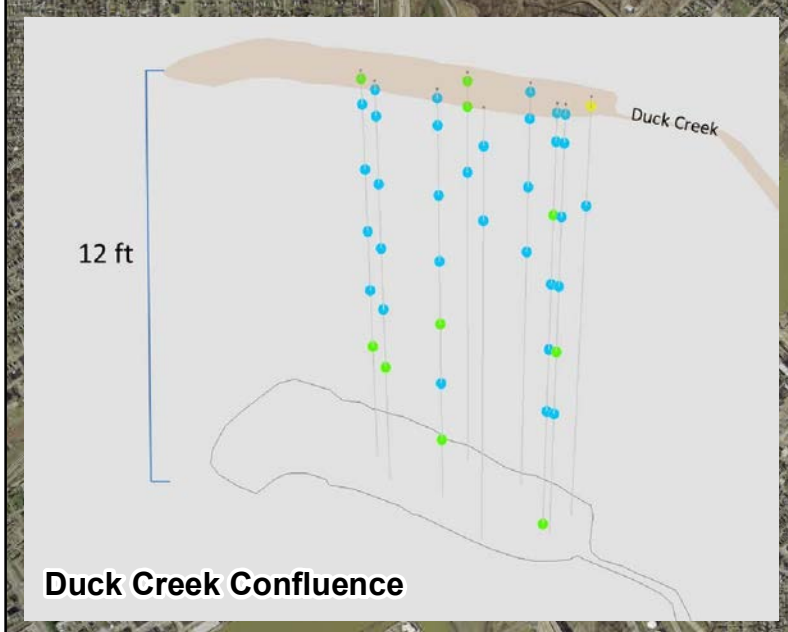
Map of Diesel Range Organics Concentrations

Figure 4-8

Date: 2/21/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\4-7 DRO.mxd





See Insets

Otter Creek

Duck Creek

Millard Ave

Field Observations
- None
- Odor
- Sheen
- Visible Oil

Sample Depth (in)
- Surface
- 0 - 24
- 24 - 48
- 48 - 72

0 0.5 1 Kilometers

N W E S

Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

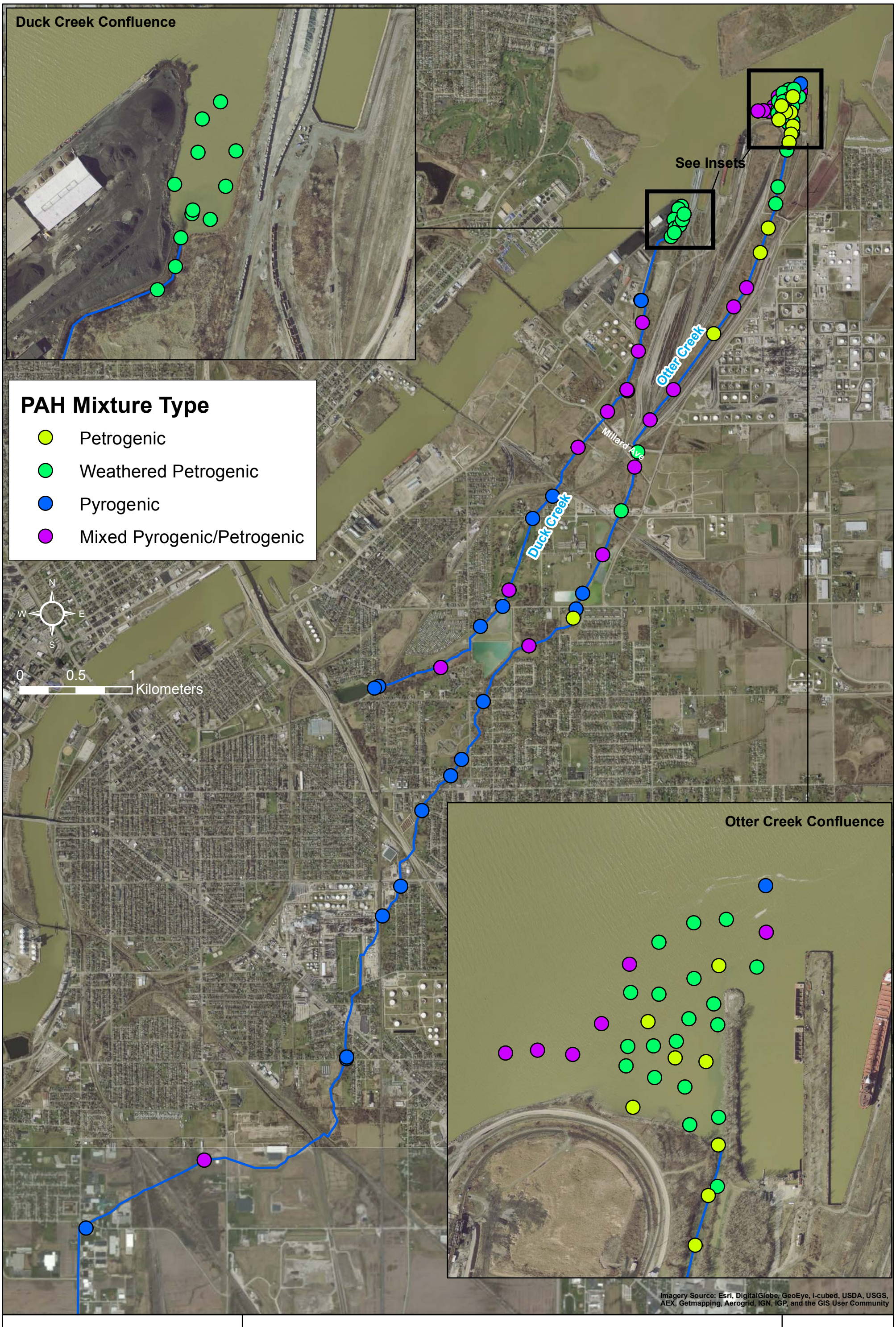
ENVIRON

Map of Field Observations

Figure 4-9

Date: 2/21/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\4-8 Field Observations.mxd



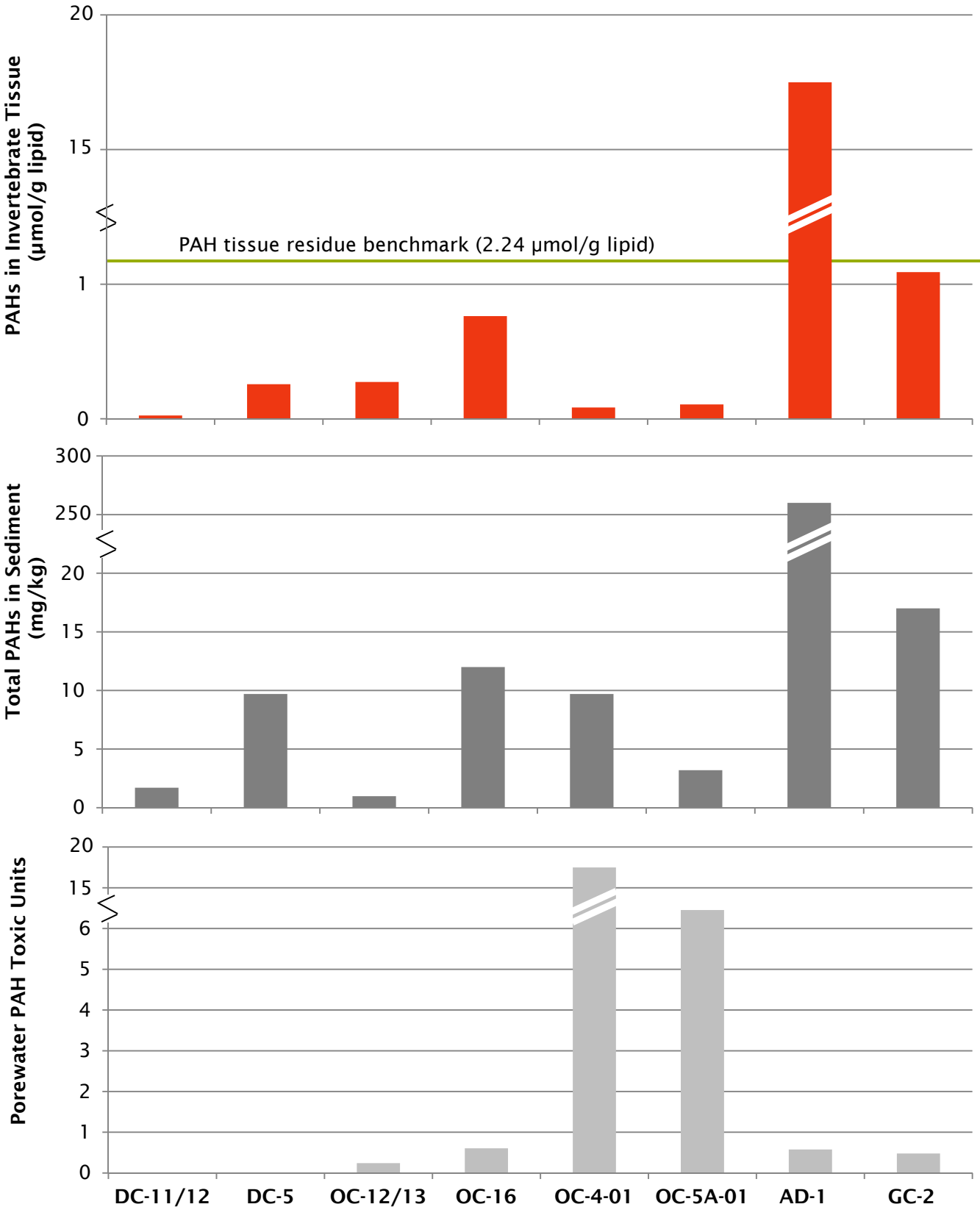
ENVIRON

Map of PAH Mixture Types

Figure 4-10

Date: 2/20/2013

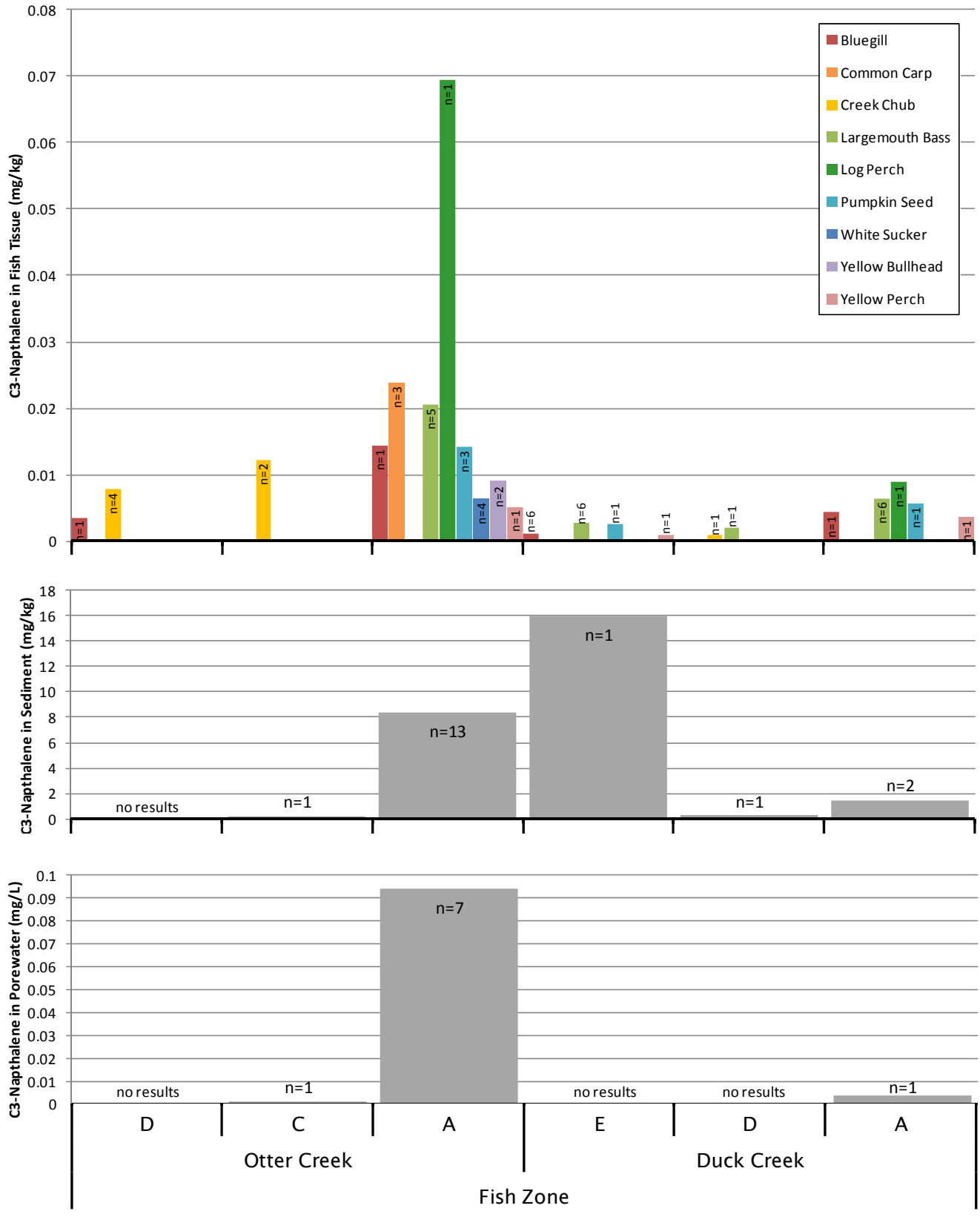
Document Path: M:\DuckandOtterCreek\GIS\MXD\4-10 PAH mixtures.mxd



ENVIRON

Comparison of PAHs in Benthic Invertebrate Tissue, Sediment, and Porewater

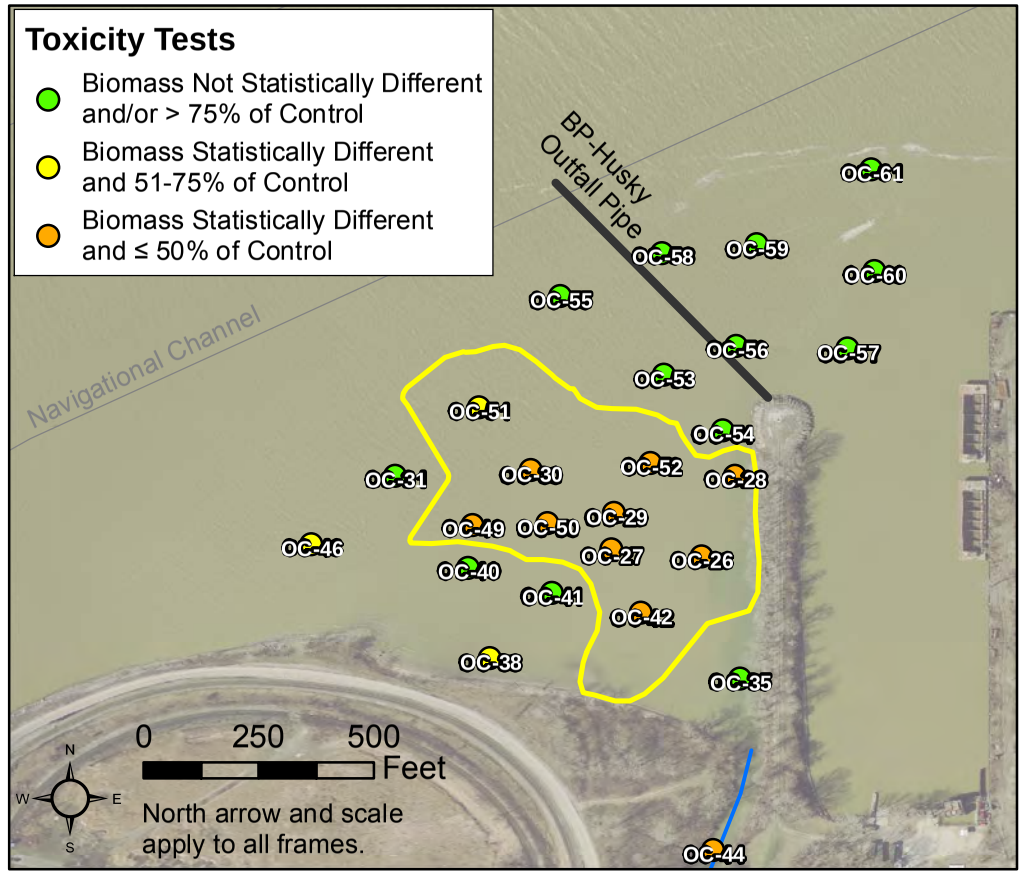
Figure 4-11

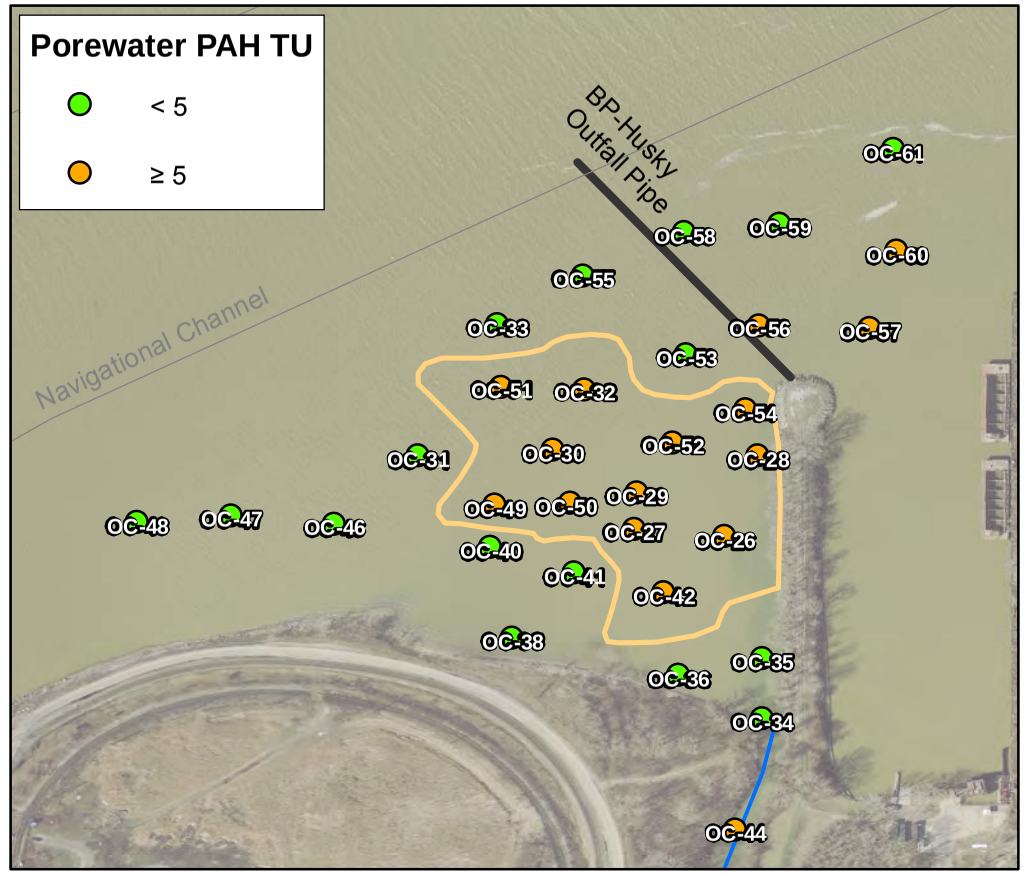


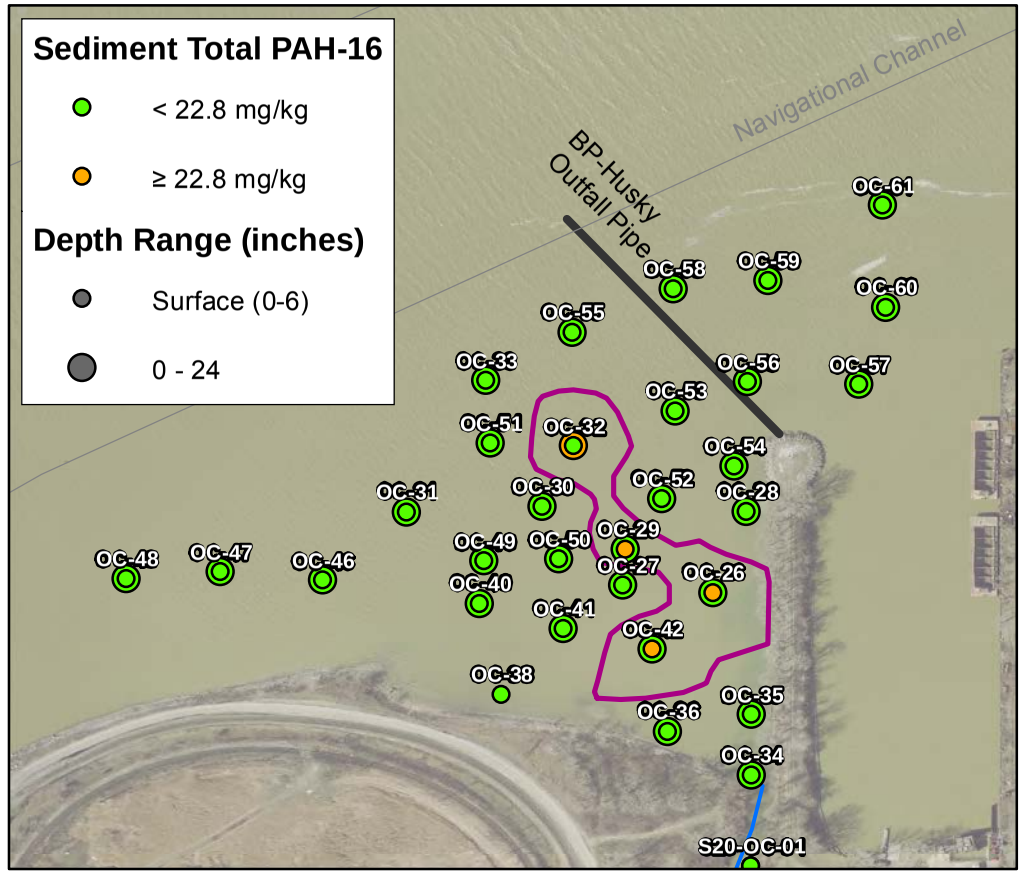
ENVIRON

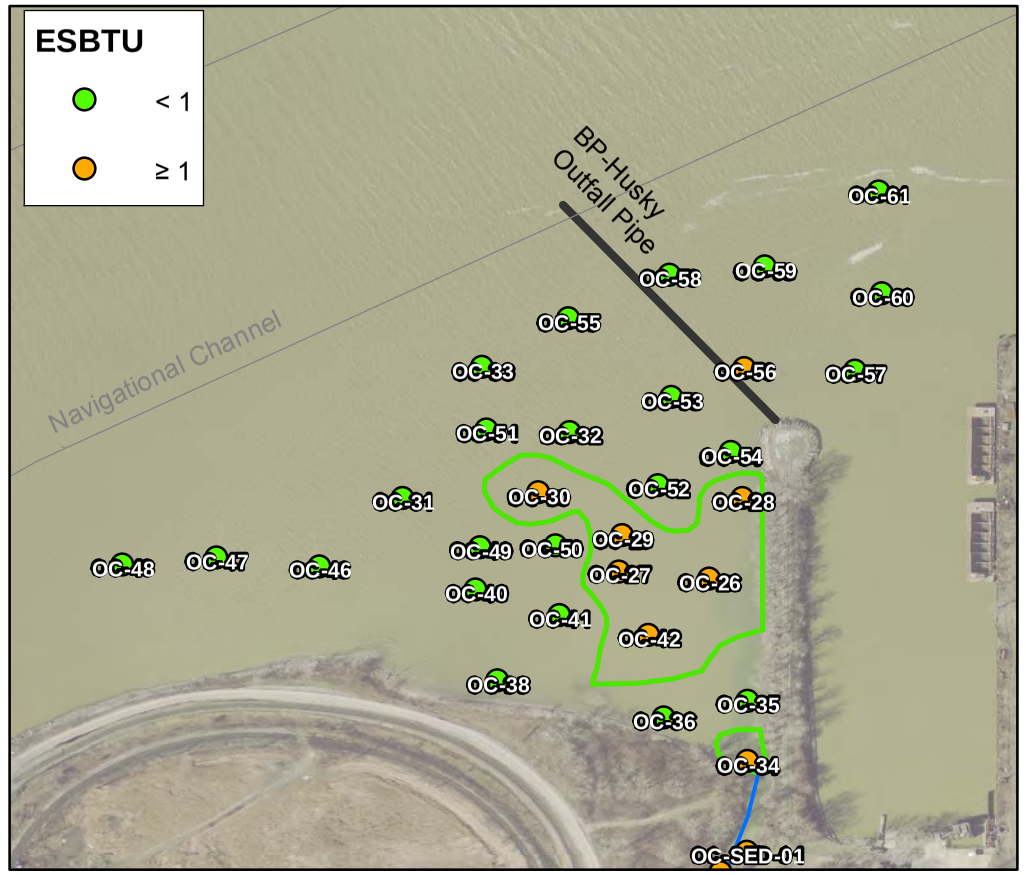
Comparison of C3-Naphthalenes in Fish Tissue, Sediment, and Porewater

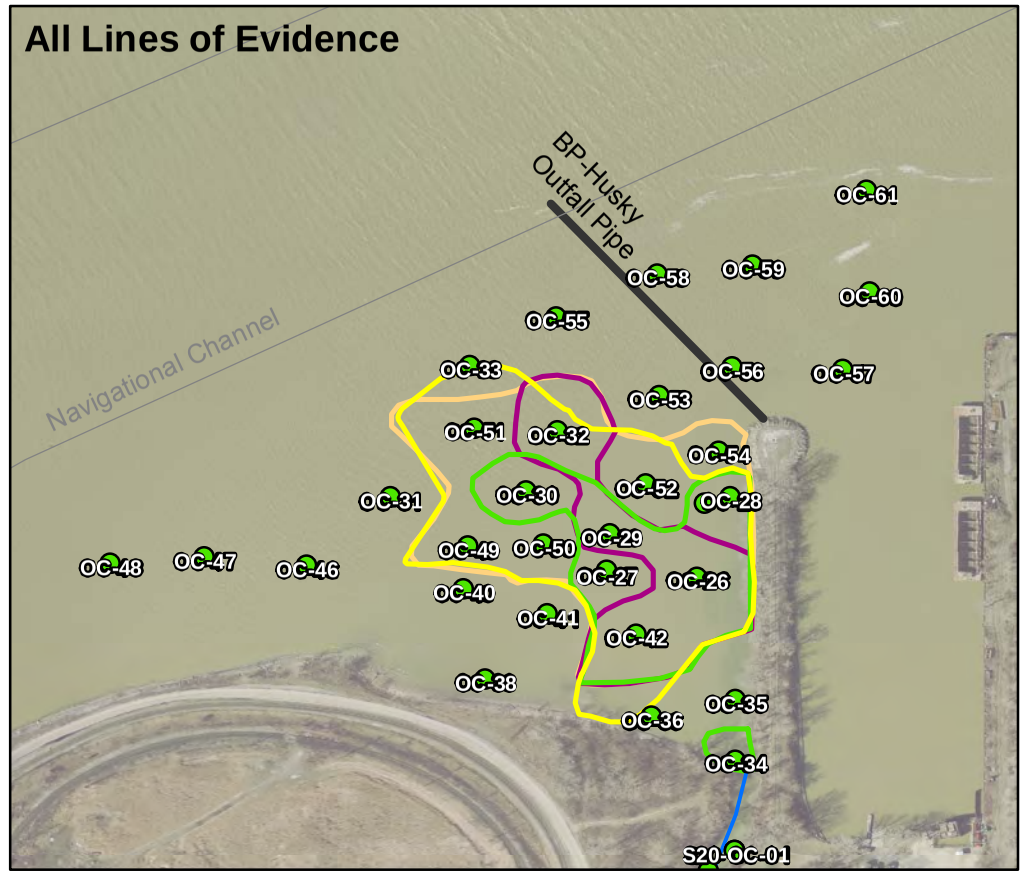
Figure 4-12

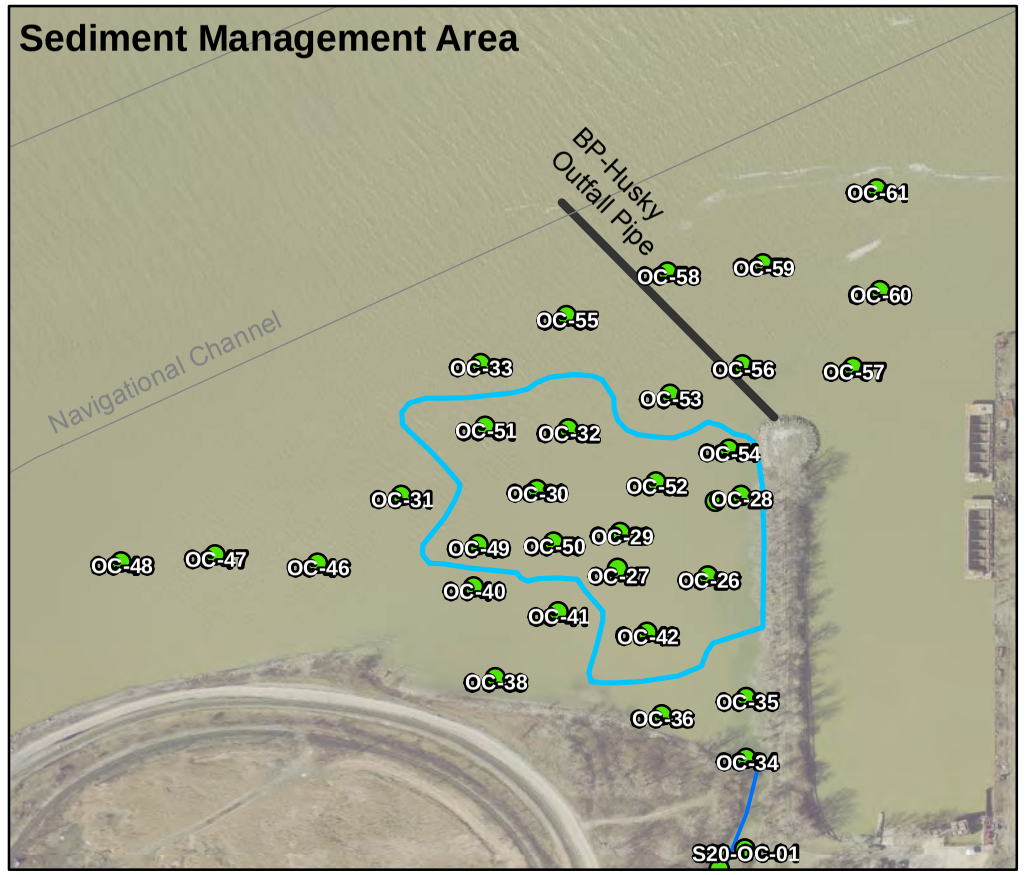












ENVIRON

Lines of Evidence to Define Sediment Management Area: Otter Creek Confluence

Figure 4-13

1/17/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\Lines of Evidence.mxd

Legend			
	PAH TU	PAH-16	DRO
Units	Unitless	mg/kg	mg/kg
Green	< 5	< 22.8	< 3100
Brown	≥ 5	≥ 22.8	≥ 3100

Sediment Management Area

0 50 100 Meters

N W E S

OC-32			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	7.65	6.21	2100
0 - 24		23.52	250
24 - 30		1.17	26

OC-51			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	5.24	0.21	
0 - 24		1.10	
24 - 48		0.96	

OC-52			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	58.16	0.83	
0 - 24		2.05	
24 - 48		1.93	
48 - 64		1.04	

OC-30			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	10.51	18.18	5300
0 - 24		13.37	910
24 - 42		1.44	41

OC-54			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	7.67	1.48	
0 - 24		2.47	
24 - 48		45.02	
48 - 65		34.25	

OC-50			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	133.62	1.16	
0 - 24		2.11	
24 - 48		1.04	

OC-28			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	15.65	13.21	2900
0 - 24		18.32	7700
24 - 48		2.37	760
48 - 52		0.13	45

OC-49			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	67.68	3.31	
0 - 24		5.25	
24 - 48		1.04	

OC-26			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	27.60	40.73	3300
0 - 24		5.21	2900
24 - 49		1.30	60

OC-29			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	26.36	31.66	6200
0 - 24		16.69	2500
24 - 52		2.63	110

OC-27			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	31.48	8.39	11000
0 - 24		3.99	700
24 - 50		0.37	61

OC-42			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	169.77	34.60	13000
0 - 23		2.63	410

Otter Creek

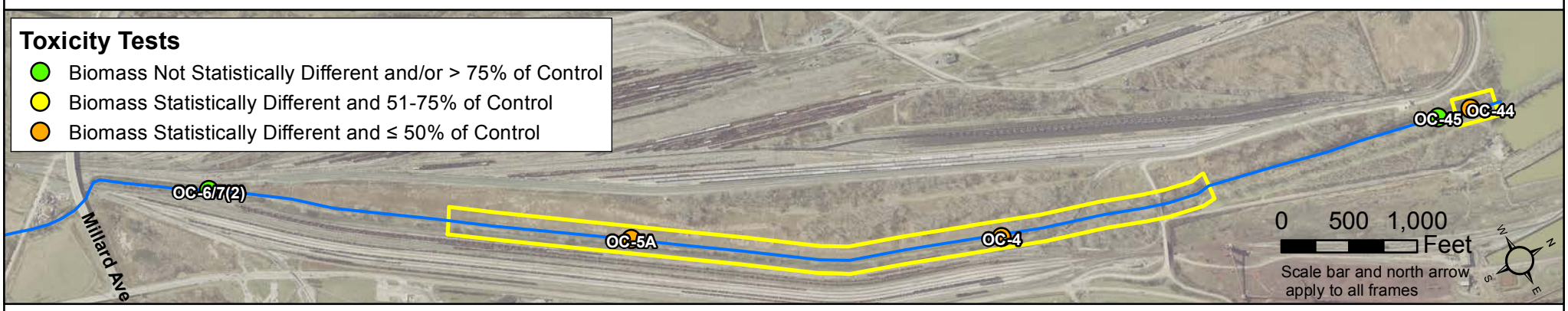
ENVIRON

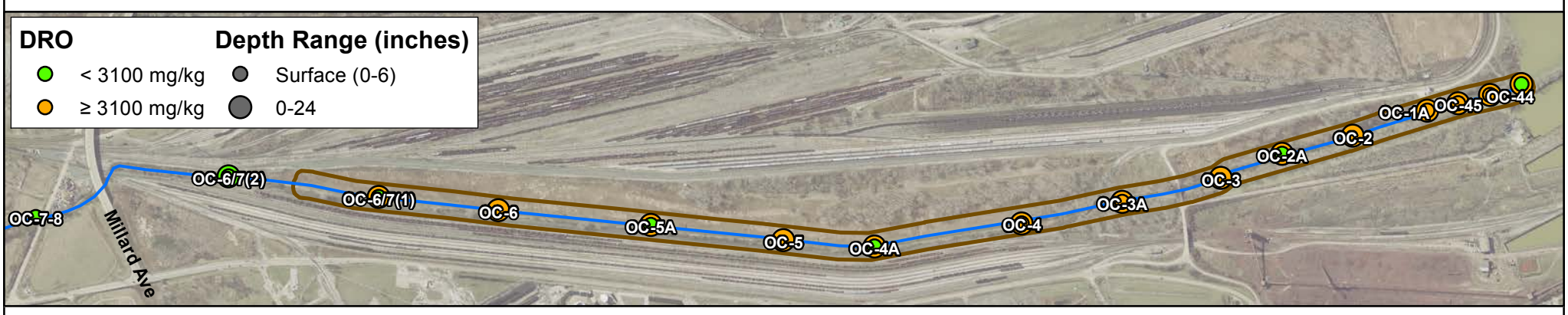
Porewater PAH, Sediment PAH-16, and DRO Concentrations: Otter Creek Confluence Sediment Management Area

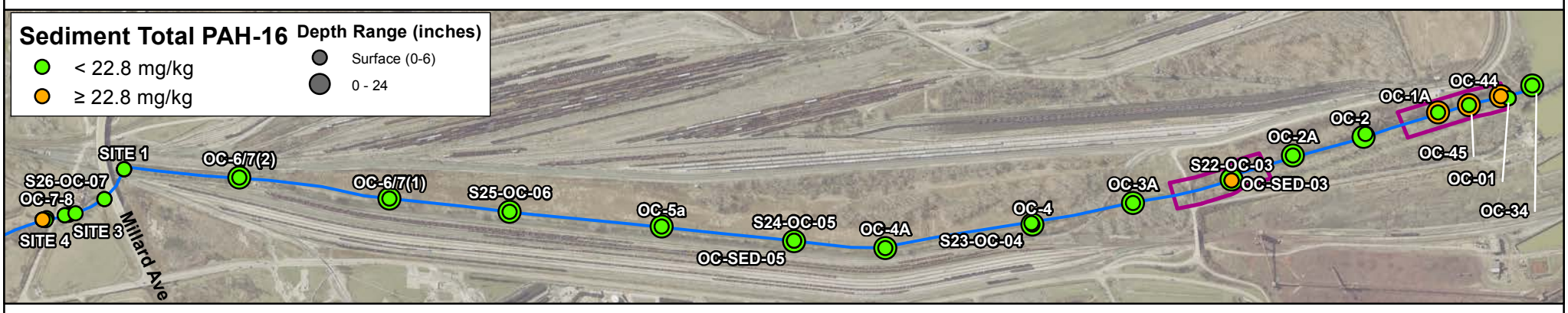
Figure 4-14

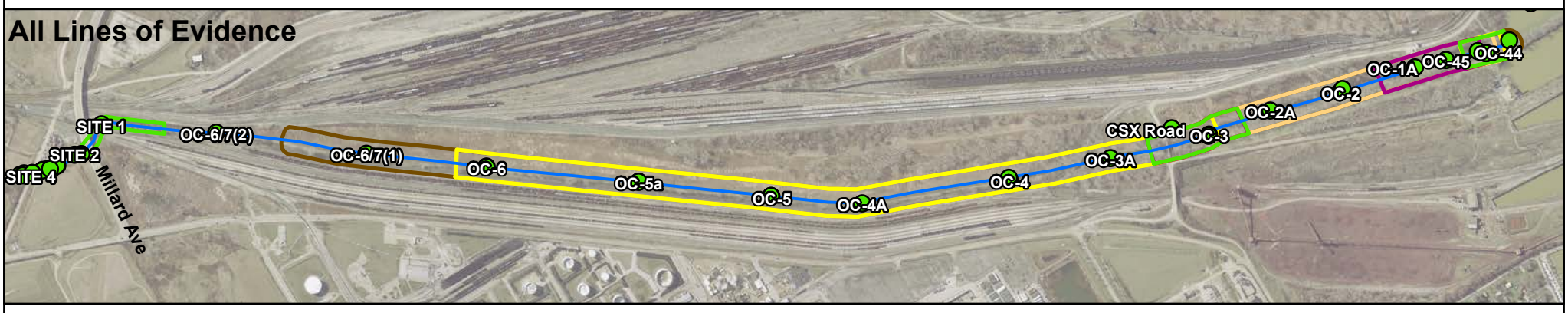
Date: 2/20/2013

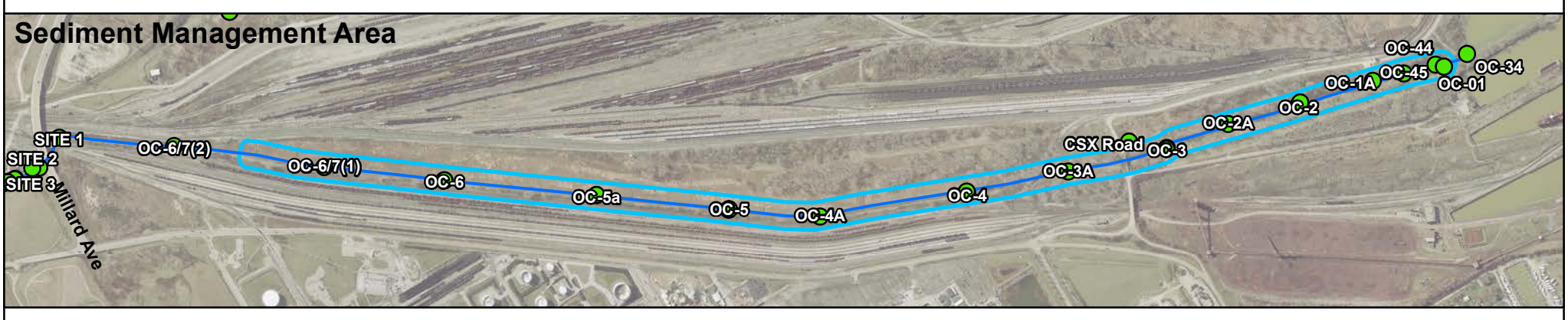
Document Path: M:\DuckandOtterCreek\GIS\MXD\ConfTagMap_revised.mxd











ENVIRON

Lines of Evidence to Define Sediment Management Area: Lower Otter Creek

Figure 4-15

2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\Lines of Evidence LOC.mxd

N
W E
S

0 0.25 0.5 Kilometers

Legend			
	PAH TU	PAH-16	DRO
Units	Unitless	mg/kg	mg/kg
Green	< 5	< 22.8	< 3100
Brown	≥ 5	≥ 22.8	≥ 3100

Sediment Management Area

OC-SED-01			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		11.86	

OC-44			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	61.50	55.60	4200
0 - 27		166.70	60000

OC-45			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	87.20	3.06	5500
0 - 25		48.65	15000

OC-1A			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		0.99	6700
0 - 12		23.70	
0 - 24			13000
24 - 48		16.43	

S21-OC-02			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		15.78	

OC-3			
Depth (in)	PAH TU	PAH-16	DRO
0 - 24		9.63	5100
24 - 48		2.70	280

OC-2			
Depth (in)	PAH TU	PAH-16	DRO
0 - 24		4.38	6600
24 - 48		22.45	8000

OC-SED-03			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		19.27	

OC-2A			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		1.09	3000
0 - 24		5.40	9900
24 - 48		8.52	
48 - 72		4.51	2400

OC-3A			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		0.42	3200
0 - 24		4.35	15000
24 - 48		4.23	9000

OC-4			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	18.07	1.14	6000
0 - 24		3.91	9500
24 - 48		3.42	11000

OC-SED-05			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		18.81	

OC-4A			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		1.15	1300
0 - 24		4.08	7600
24 - 48		4.03	5400

S25-OC-06			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		5.66	

OC-5			
Depth (in)	PAH TU	PAH-16	DRO
0 - 24		3.88	8400
24 - 48		5.23	27000

OC-6/7(1)			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab		1.72	170
0 - 24		2.56	4800
24 - 48		2.72	9100

OC-5A			
Depth (in)	PAH TU	PAH-16	DRO
Surface Grab	6.59	0.45	2600
0 - 24		3.76	5600
24 - 48		3.20	7000

OC-6			
Depth (in)	PAH TU	PAH-16	DRO
0 - 24		3.76	10000
24 - 48		2.96	5800

ENVIRON

Porewater PAH, Sediment PAH-16, and DRO Concentrations: Lower Otter Creek Sediment Management Area

Figure 4-16

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\TagMap LOC revised.mxd

Arsenic (mg/kg)

- < PEC (33 mg/kg)
- < PEC x 2 (66 mg/kg)
- > PEC x 2 (66 mg/kg)

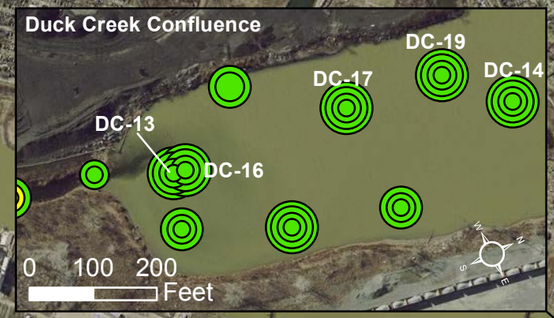
Depth Range (in)

- Surface
- 0 - 24
- 24 - 48
- 48 - 72

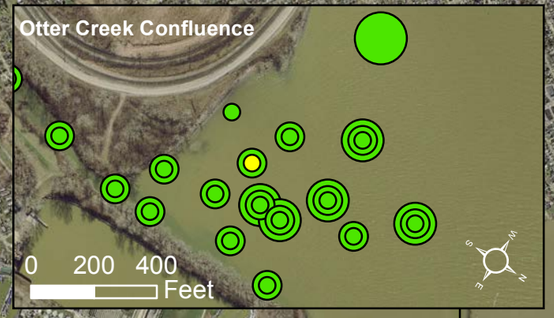
Samples DC-13, DC-14, DC-16, DC-17, and DC-19 extend deeper than 72 inches; there are no PEC exceedances in these deeper intervals.

PEC x 2: The PEC is doubled to provide a visual reference point for understanding relative sediment concentrations.

Duck Creek Confluence

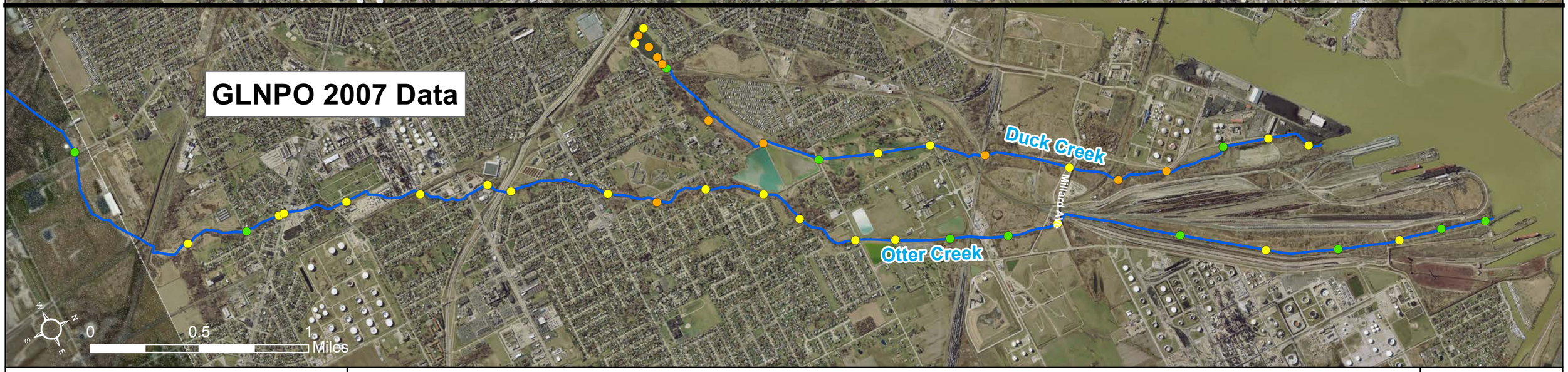


Otter Creek Confluence



All Other Data

GLNPO 2007 Data



ENVIRON

Map of Sediment Screening Results, Arsenic

Figure 5-1

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\5-1 Arsenic.mxd

Chromium (mg/kg)

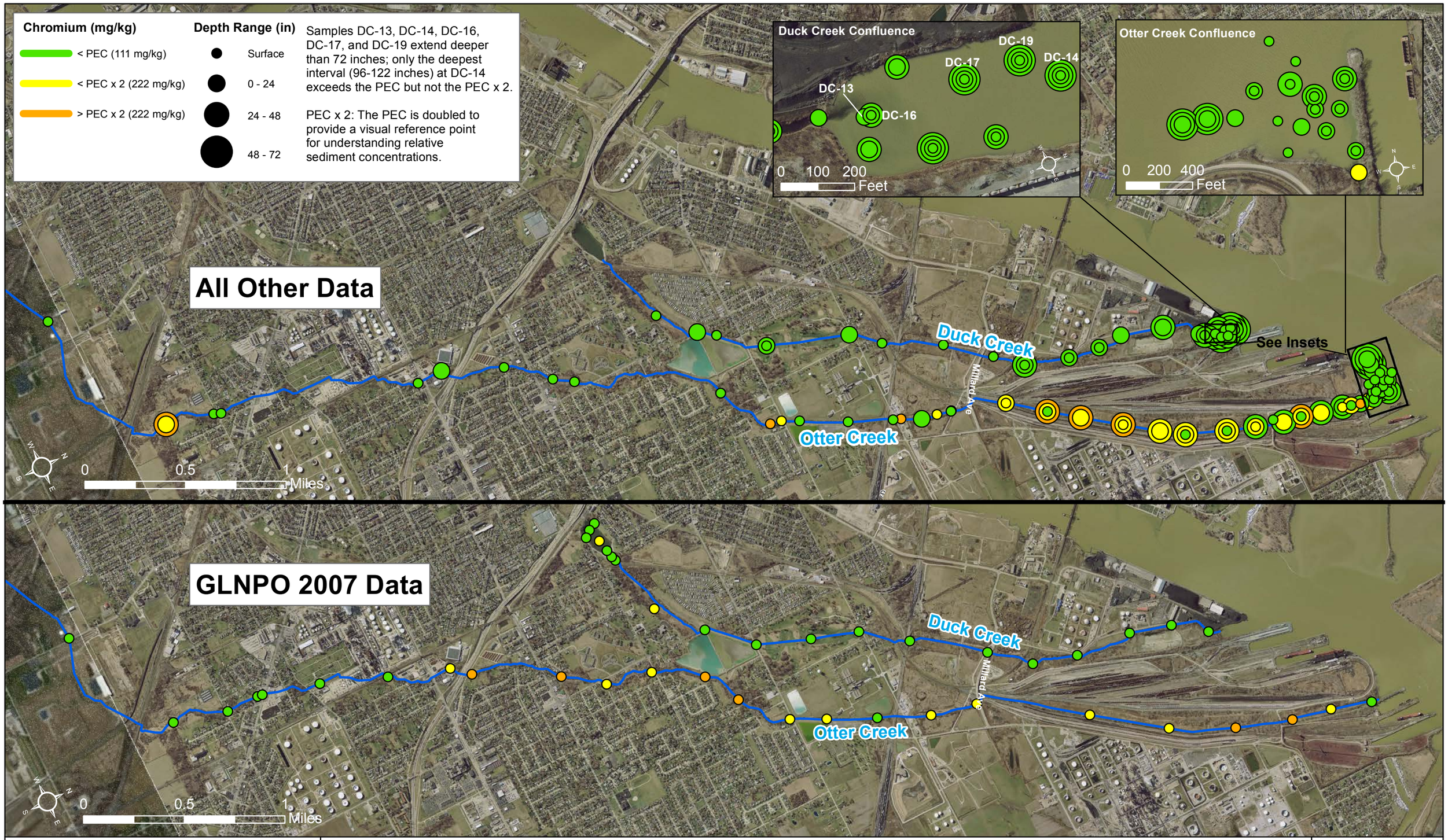
- < PEC (111 mg/kg)
- < PEC x 2 (222 mg/kg)
- > PEC x 2 (222 mg/kg)

Depth Range (in)

- Surface
- 0 - 24
- 24 - 48
- 48 - 72

Samples DC-13, DC-14, DC-16, DC-17, and DC-19 extend deeper than 72 inches; only the deepest interval (96-122 inches) at DC-14 exceeds the PEC but not the PEC x 2.

PEC x 2: The PEC is doubled to provide a visual reference point for understanding relative sediment concentrations.



ENVIRON

Map of Sediment Screening Results, Chromium

Figure 5-2

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\5-2 Chromium.mxd

Otter Creek Confluence

See Insets

Duck Creek

Millard Ave

Otter Creek

Legend

Copper (mg/kg)

< PEC (149.0 mg/kg)

< PEC x 2 (298.0 mg/kg)

> PEC x 2 (298.0 mg/kg)

Depth Range (in)

Surface

0 - 24

24 - 48

48 - 72

Samples DC-13, DC-14, DC-16 DC-17, and DC-19 extend deeper than 72 inches; there are no PEC exceedances in these deeper intervals

PEC x 2: The PEC is doubled to provide a visual reference point for understanding relative sediment concentrations.

Total copper not analyzed in GLNPO 2007 samples.

0 0.5 1 Miles

N W E S

DC-14

DC-19

DC-17

DC-16

DC-13

Duck Creek Confluence

Imagery Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

ENVIRON

Map of Sediment Screening Results Copper

Figure 5-3

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\5-3 Copper.mxd

Lead (mg/kg)

- < PEC (128 mg/kg)
- < PEC x 2 (256 mg/kg)
- > PEC x 2 (256 mg/kg)

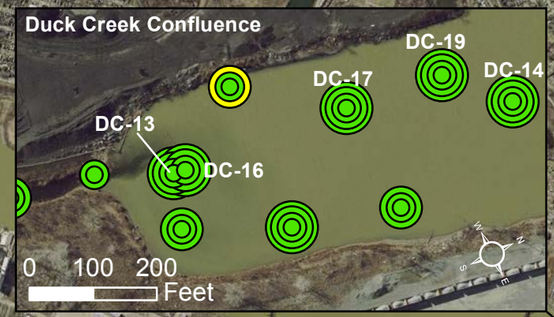
Depth Range (in)

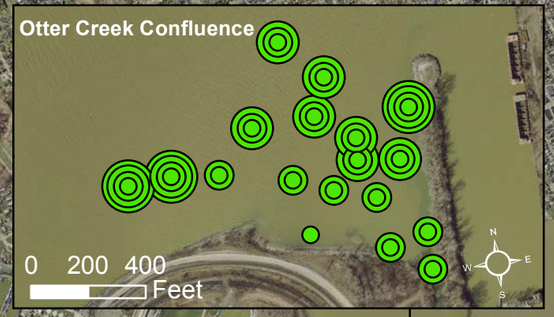
- Surface
- 0 - 24
- 24 - 48
- 48 - 72

Samples DC-13, DC-14, DC-16, DC-17, and DC-19 extend deeper than 72 inches; there are no PEC exceedances in these deeper intervals.

PEC x 2: The PEC is doubled to provide a visual reference point for understanding relative sediment concentrations.

All Other Data





See Insets

Duck Creek

Otter Creek

Millard Ave

0 0.5 1 Miles

GLNPO 2007 Data

Duck Creek

Otter Creek

Millard Ave

0 0.5 1 Miles

ENVIRON

Map of Sediment Screening Results, Lead

Figure 5-4

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\5-4 Lead.mxd

Otter Creek Confluence

See Insets

Duck Creek

Millard Ave

Otter Creek

Legend

Nickel

- < PEC (48.6 mg/kg)
- < PEC x 2 (97.2 mg/kg)
- > PEC x 2 (97.2 mg/kg)

Depth Range (in)

- Surface
- 0 - 24
- 24 - 48
- 48 - 72

Samples DC-13, DC-14, DC-16, DC-17, and DC-19 extend deeper than 72 inches; only the deepest interval (96-122 inches) at DC-14 exceeds the PEC but not the PEC x 2.

PEC x 2: The PEC is doubled to provide a visual reference point for understanding relative sediment concentrations.

Total nickel not analyzed in GLNPO 2007 samples.

0 0.5 1 Miles

N W E S

DC-14
DC-19
DC-17
DC-16
DC-13

Duck Creek Confluence

Imagery Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

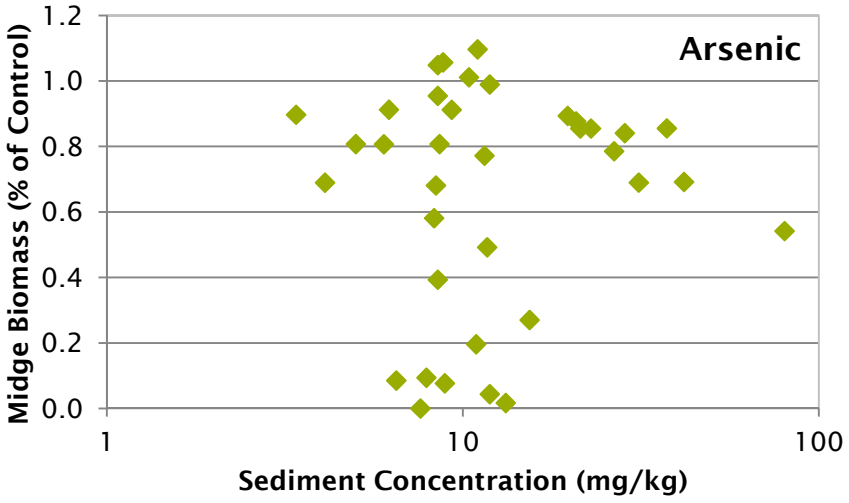
ENVIRON

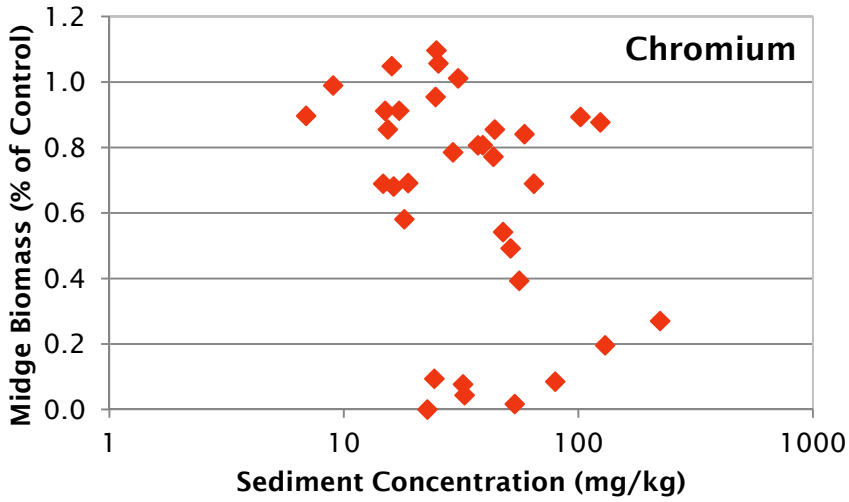
Map of Sediment Screening Results Nickel

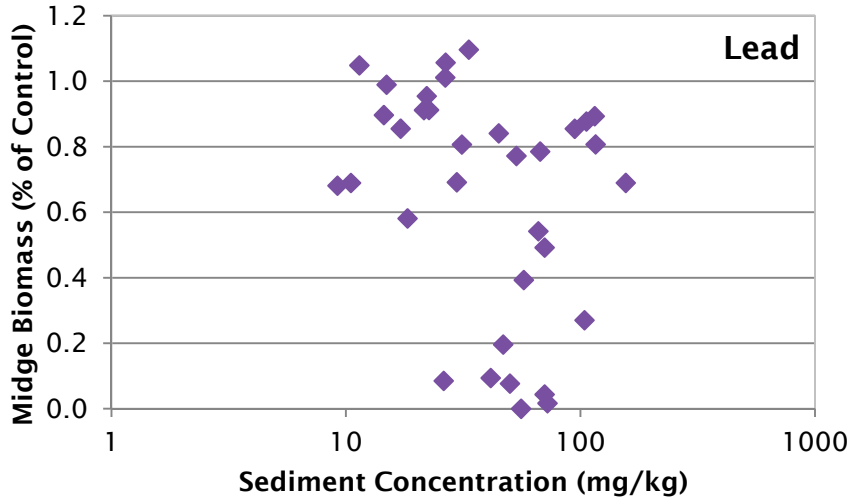
Figure 5-5

Date: 2/20/2013

Document Path: M:\DuckandOtterCreek\GIS\MXD\5-5 Nickel.mxd

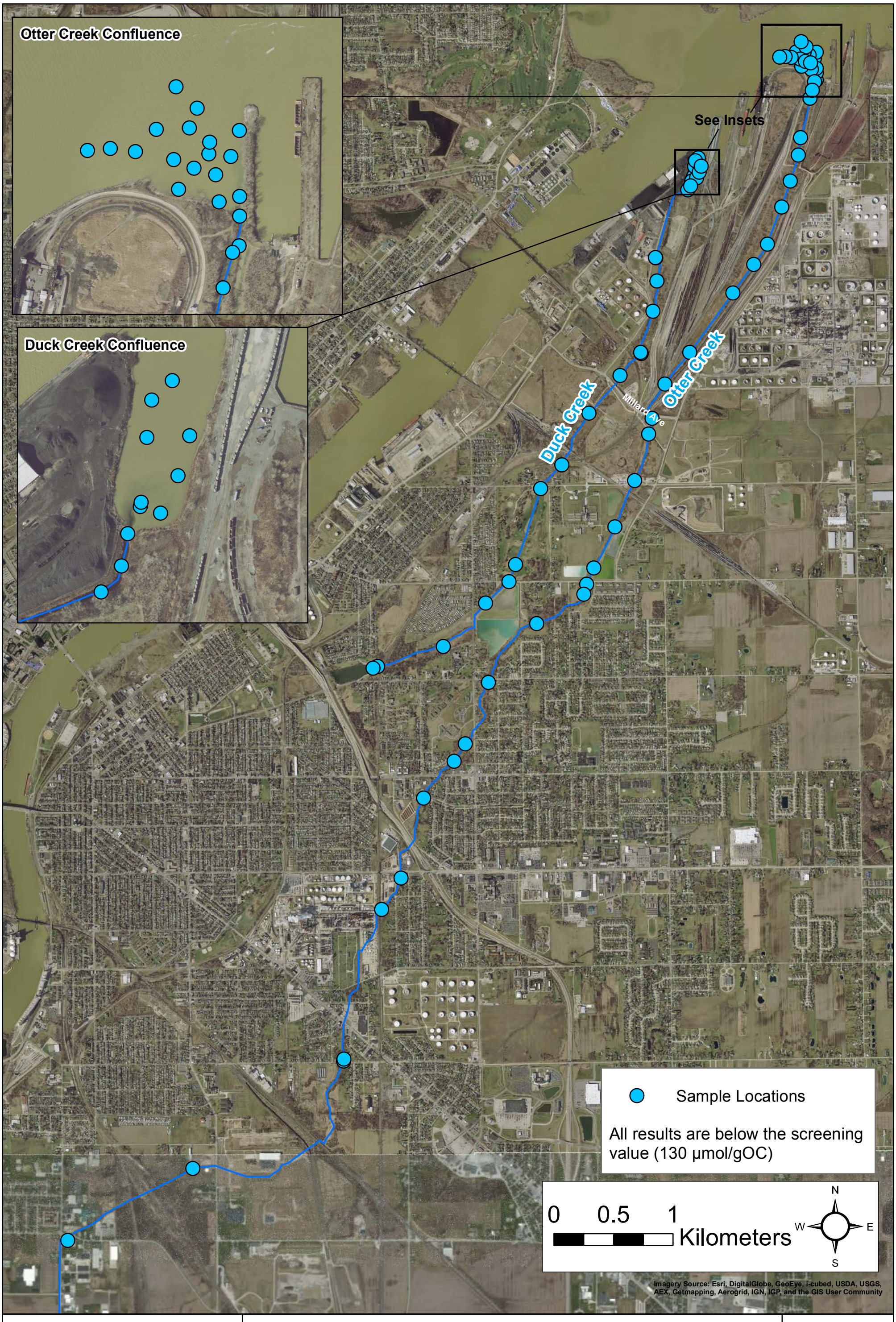






Note: Arsenic, chromium, and lead were detected in all samples.

ENVIRON	Quantitative Exposure Response Relationship for Sediment Metal Effects on Midge Biomass	Figure 5-6



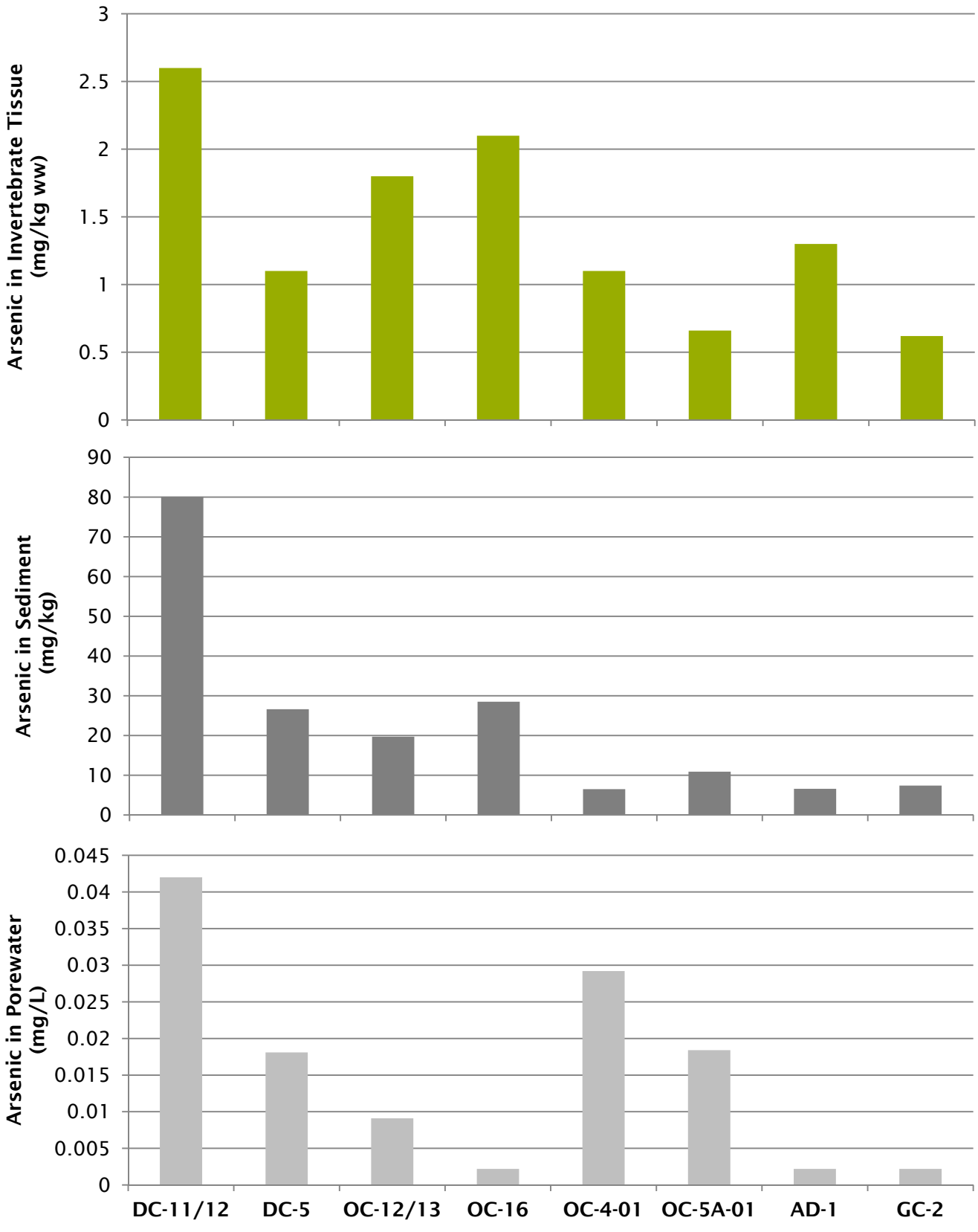
ENVIRON

Map of AVS and SEM Screening Results

Figure 5-7

Date: 2/20/2013

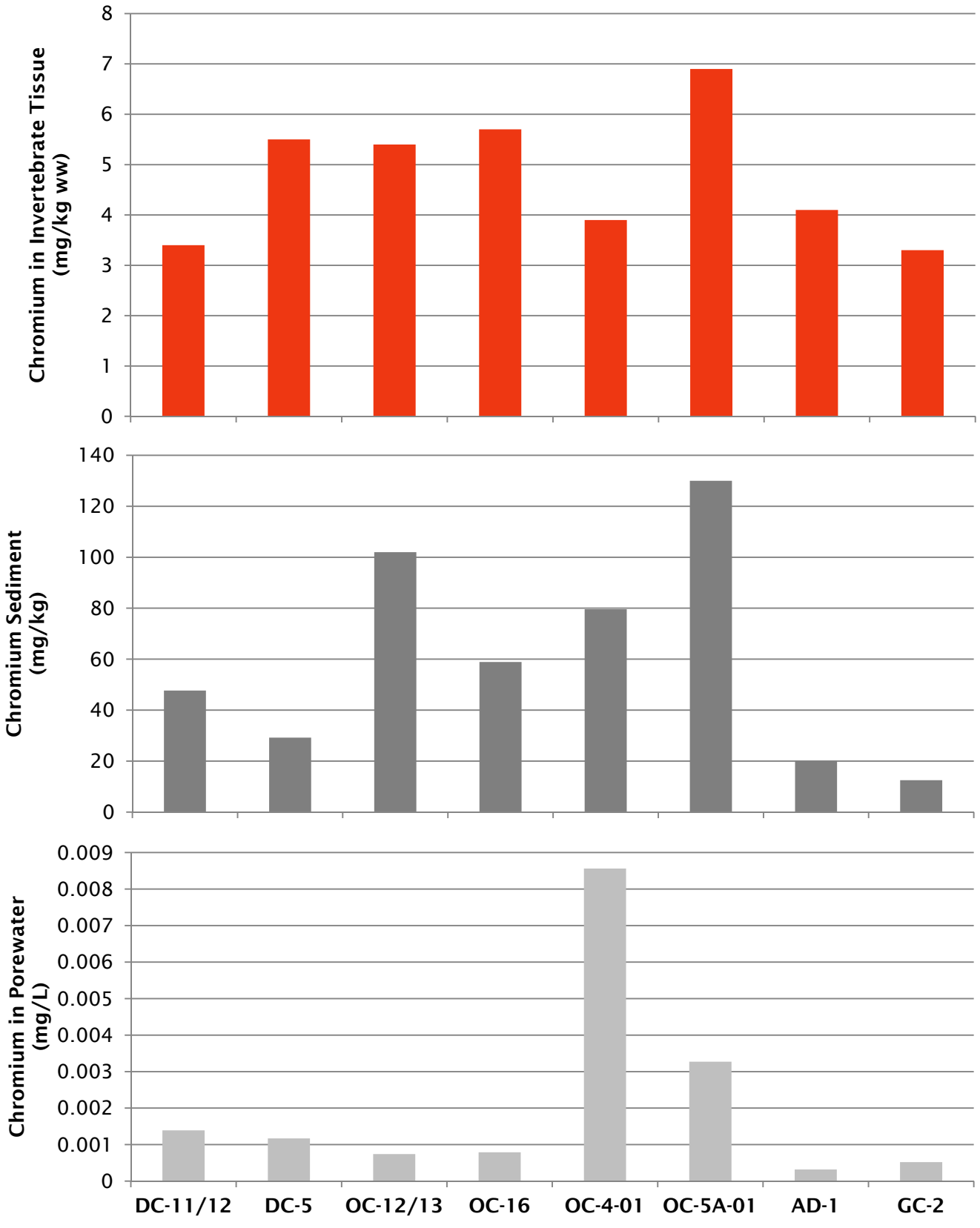
Document Path: M:\DuckandOtterCreek\GIS\MXD\5-7 AVS SEM.mxd



ENVIRON

Comparison of Arsenic in Benthic Invertebrate Tissue, Sediment, and Porewater

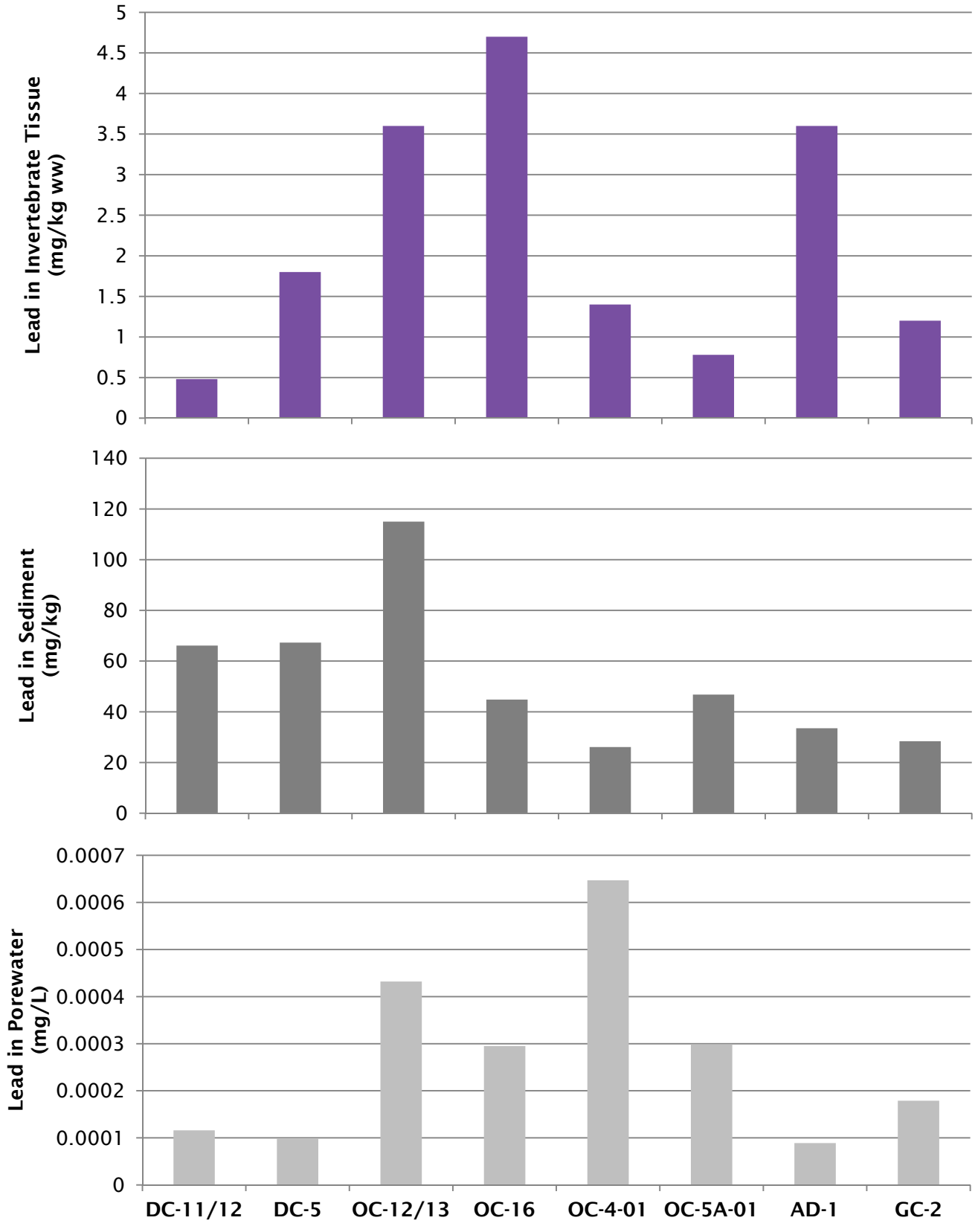
Figure 5-8



ENVIRON

Comparison of Chromium in Benthic Invertebrate Tissue, Sediment, and Porewater

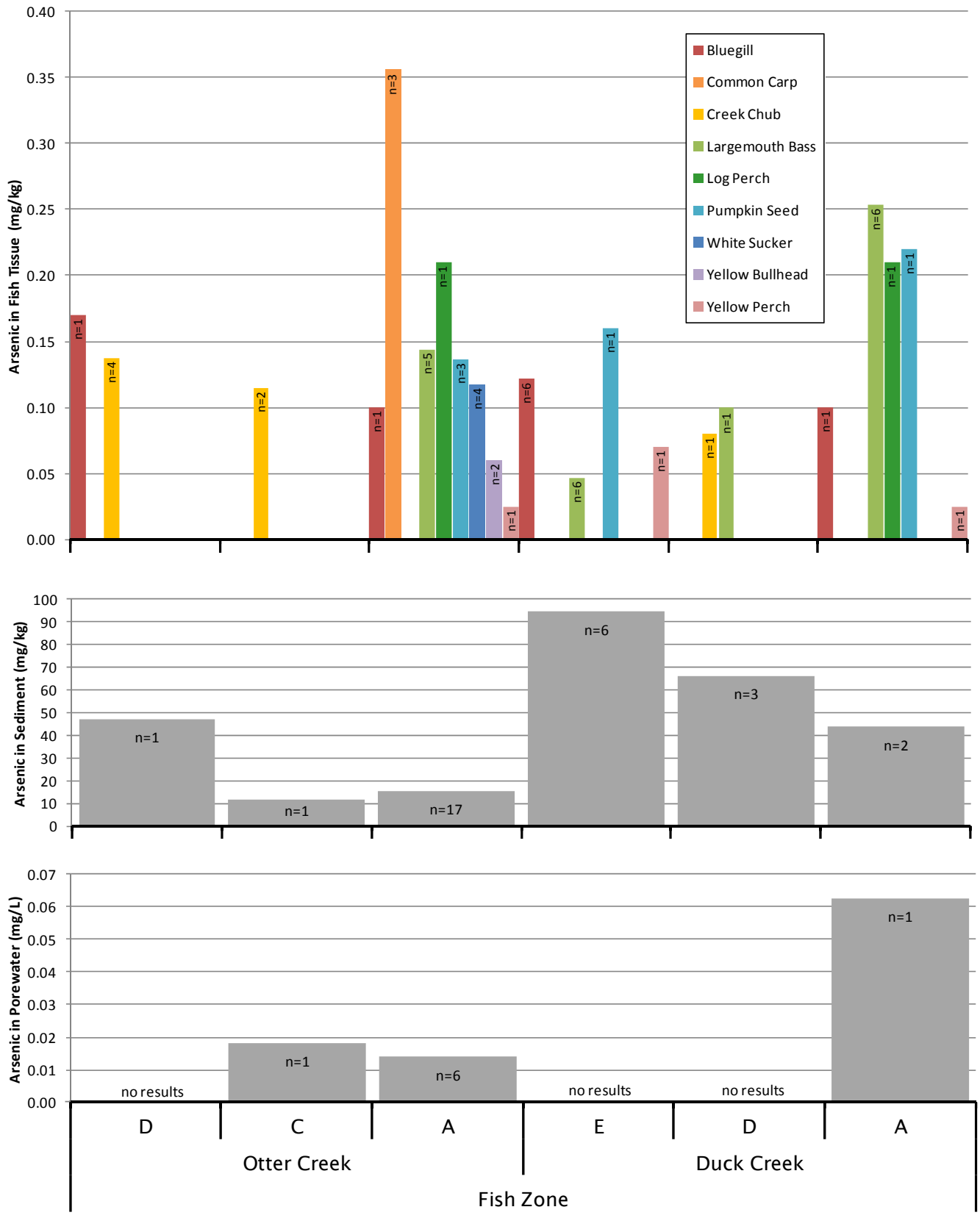
Figure 5-9



ENVIRON

Comparison of Lead in Benthic Invertebrate Tissue, Sediment, and Porewater

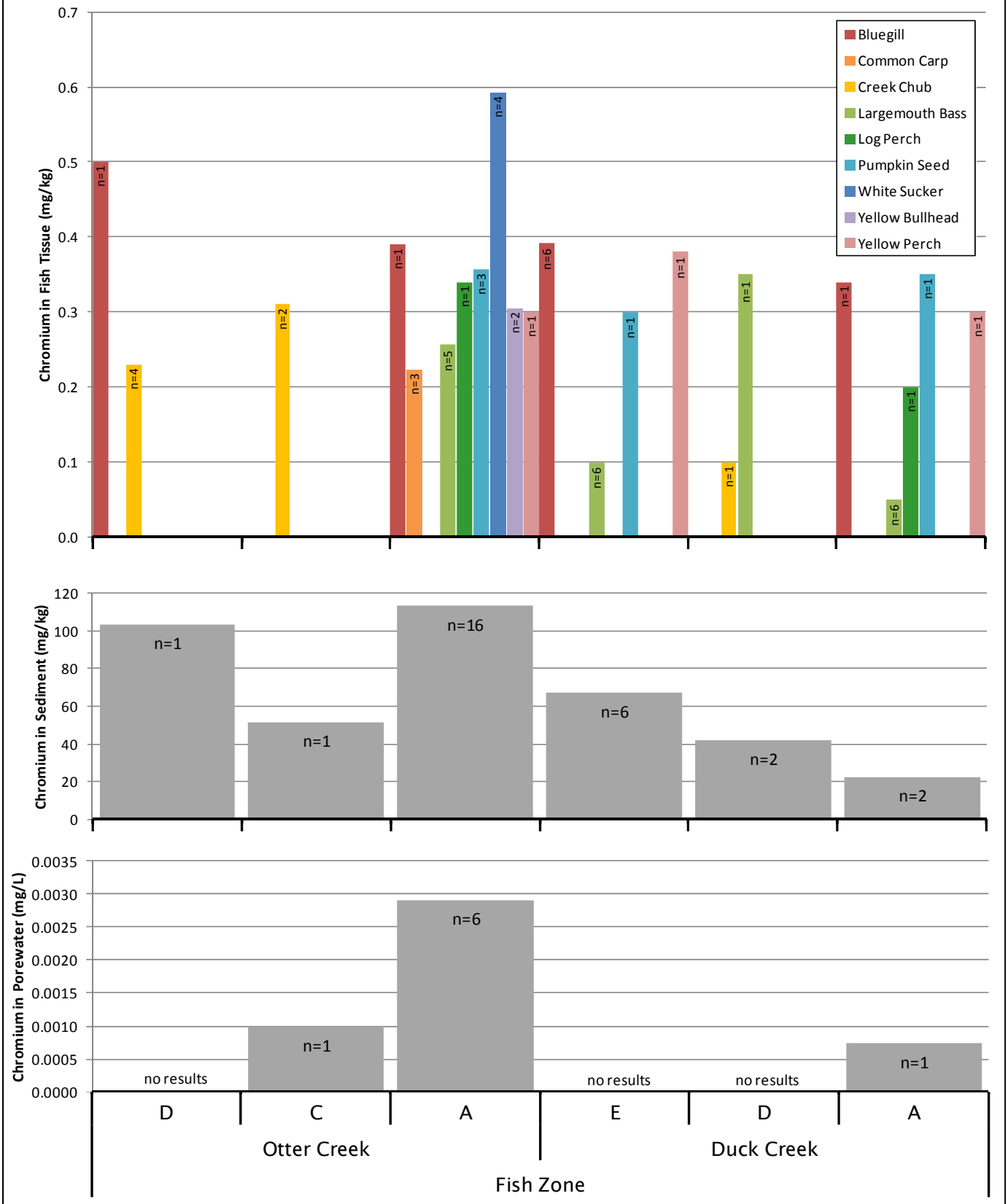
Figure 5-10



ENVIRON

Comparison of Arsenic in Fish Tissue, Sediment, and Porewater

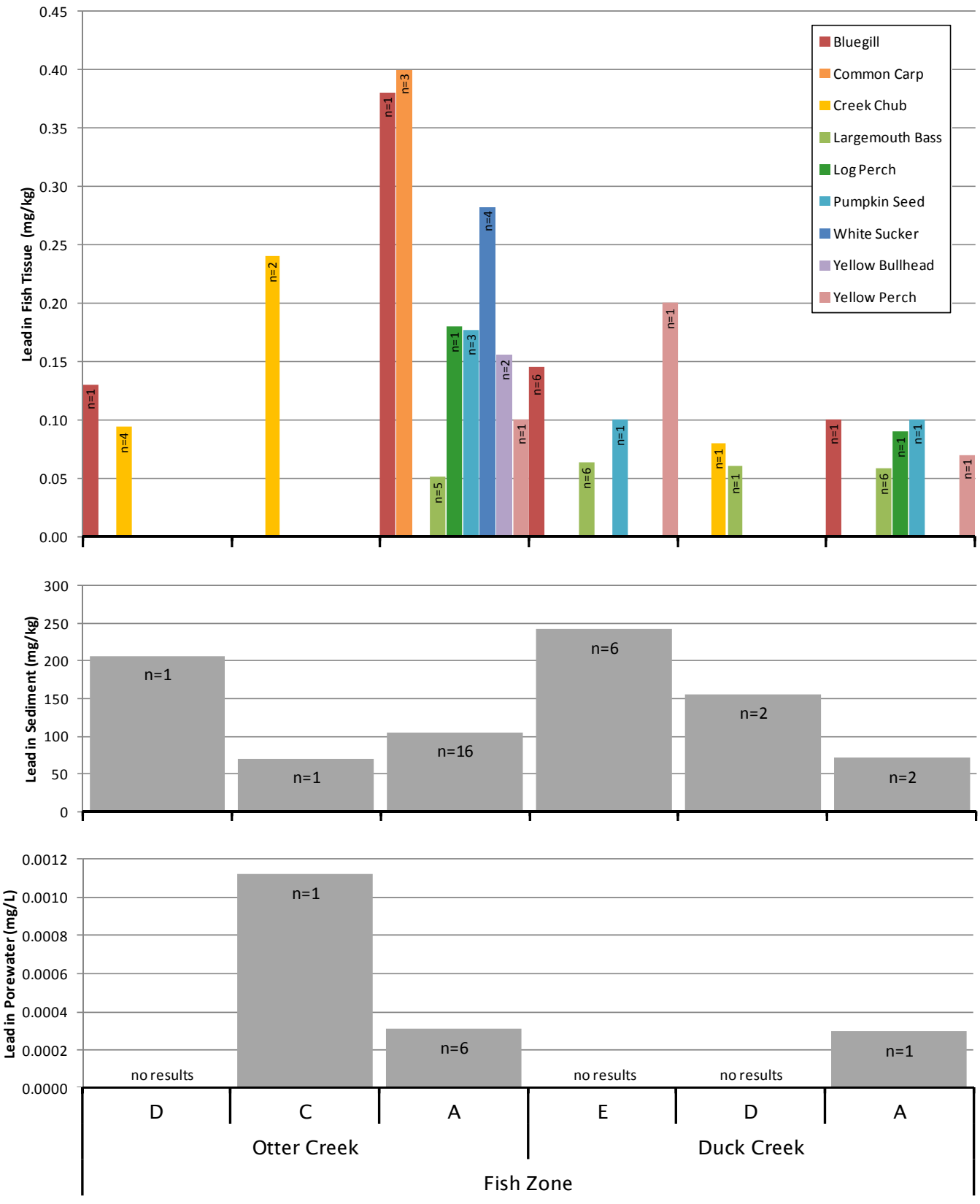
Figure 5-11



ENVIRON

Comparison of Chromium in Fish Tissue, Sediment, and Porewater

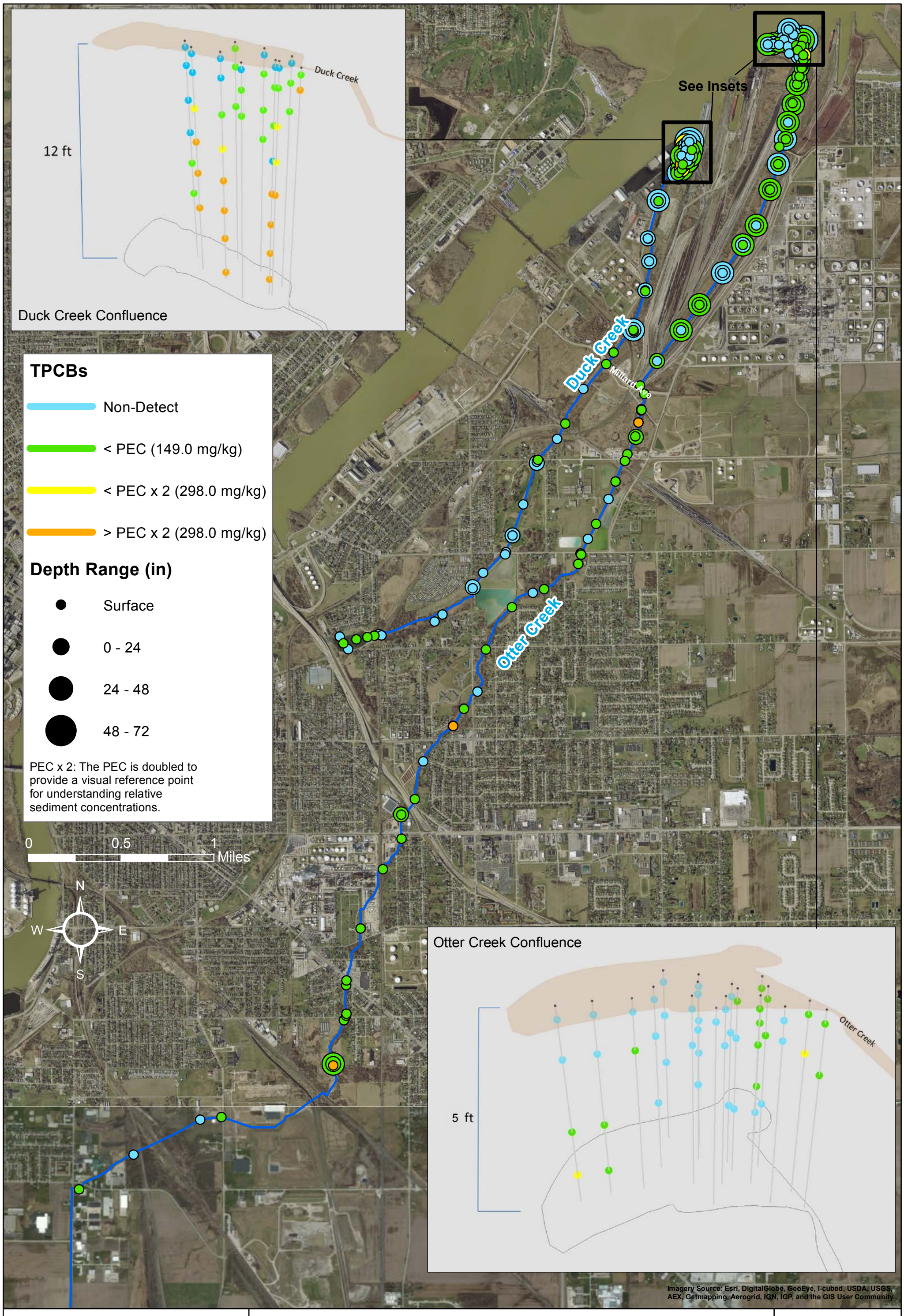
Figure 5-12



ENVIRON

Comparison of Lead in Fish Tissue, Sediment, and Porewater

Figure 5-13



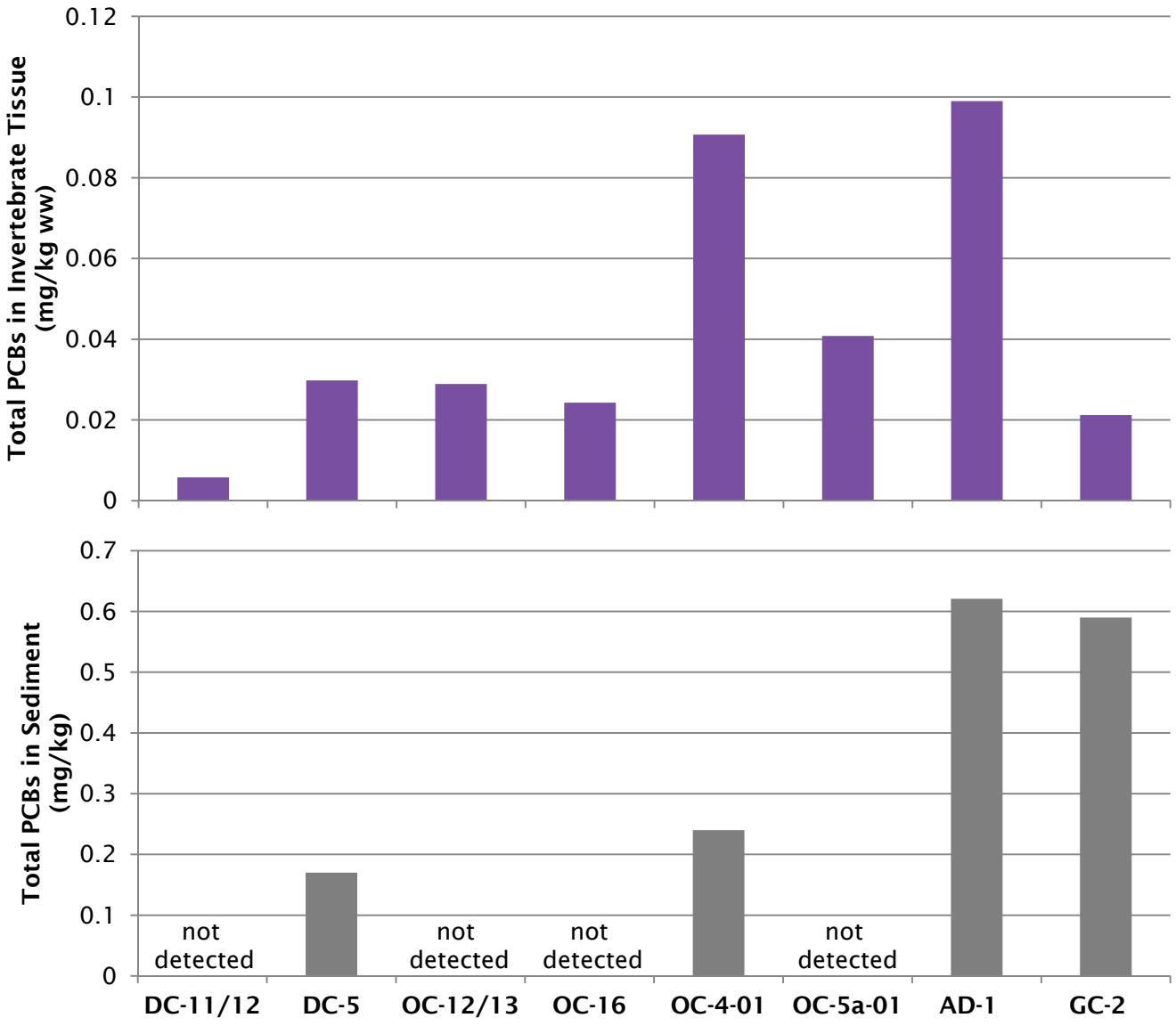
ENVIRON

Sediment Screening Results Total PCBs

Figure 6-1

Date: 2/20/2013

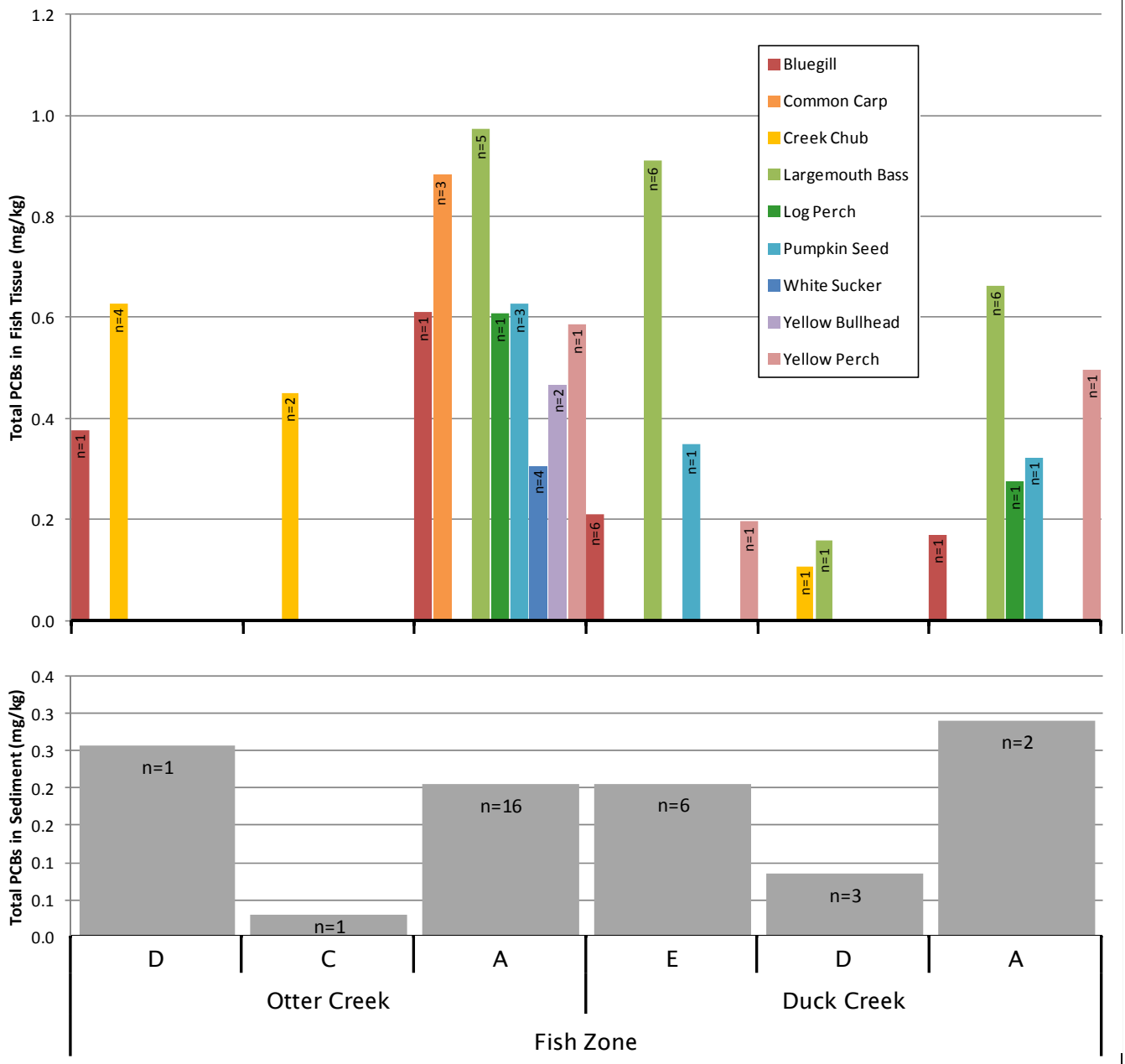
Document Path: M:\DuckandOtterCreek\GIS\MXD\6-1 Total PCBs.mxd



ENVIRON

Comparison of PCBs in Benthic Invertebrate Tissue and Sediment

Figure 6-2



ENVIRON

Comparison of PCBs in Fish Tissue and Sediment

Figure 6-3

Attachment 1

Analytical Chemistry Results

Attachment 1A Data for Supplemental Data Evaluation is provided as an Excel file.

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
SED-T-20	Otter	Envirosafe 2006-2007	8/29/2007	0-6	2.7	2.4	NA	NA	NA	NA
SED-T-20	Otter	Envirosafe 2006-2007	10/15/2007	0-6	20.8	10.4	28.8	14.4	1.9	NA
SED-T-20A	Otter	Envirosafe 2006-2007	8/29/2007	0-6	3.3	8.0	NA	NA	NA	NA
SED-T-20A	Otter	Envirosafe 2006-2007	10/15/2007	0-6	0.3	0.2	2.2	1.1	0.2	NA
SITE 1	Otter	Envirosafe 2006-2007	7/17/2006	0-6	22.4	11.2	NA	NA	NA	NA
SITE 1	Otter	Envirosafe 2006-2007	8/28/2007	0-6	10.9	26.5	NA	NA	NA	NA
SITE 1	Otter	Envirosafe 2006-2007	10/15/2007	0-6	6.8	3.4	20.2	10.1	1.5	NA
SITE 3	Otter	Envirosafe 2006-2007	10/15/2007	0-6	1.4	0.7	5.5	2.8	0.4	NA
SITE 4	Otter	Envirosafe 2006-2007	7/17/2006	0-6	4.7	2.4	NA	NA	NA	NA
SITE 4	Otter	Envirosafe 2006-2007	8/28/2007	0-6	23.5	7.6	NA	NA	NA	NA
SITE 4	Otter	Envirosafe 2006-2007	10/15/2007	0-6	31.1	15.6	189.1	94.5	13.4	NA
SITE 6	Otter	Envirosafe 2006-2007	8/28/2007	0-6	25.7	13.5	NA	NA	NA	NA
SITE 6	Otter	Envirosafe 2006-2007	10/15/2007	0-6	2.2	1.1	3.9	1.9	0.2	NA
SITE 9	Otter	Envirosafe 2006-2007	8/28/2007	0-6	25.3	6.2	NA	NA	NA	NA
SITE 9	Otter	Envirosafe 2006-2007	10/15/2007	0-6	11.5	5.7	23.0	11.5	1.5	NA
DC-1	Duck	GLLA 2010-2011	10/12/2010	0-24	2.5	0.9	NA	NA	NA	NA
DC-1	Duck	GLLA 2010-2011	10/12/2010	24-48	1.8	2.2	NA	NA	NA	NA
DC-10/11	Duck	GLLA 2010-2011	10/19/2010	0-6	20.0	3.0	27.3	4.0	0.5	NA
DC-11	Duck	GLLA 2010-2011	10/18/2010	0-24	8.6	1.5	NA	NA	NA	NA
DC-11/12	Duck	GLLA 2010-2011	10/19/2010	0-6	1.4	0.1	3.1	0.1	0.0	0.2
DC-13	Duck	GLLA 2010-2011	11/2/2010	0-6	29.5	0.9	91.8	2.7	0.4	0.2
DC-13	Duck	GLLA 2010-2011	11/2/2010	0-24	0.2	0.0	NA	NA	NA	NA
DC-13	Duck	GLLA 2010-2011	11/2/2010	24-48	0.1	0.0	NA	NA	NA	NA
DC-13	Duck	GLLA 2010-2011	11/2/2010	48-72	1.7	0.3	NA	NA	NA	NA
DC-13	Duck	GLLA 2010-2011	11/2/2010	72-96	13.6	1.3	NA	NA	NA	NA
DC-14	Duck	GLLA 2010-2011	11/3/2010	0-6	4.8	0.5	14.0	1.6	0.2	0.2
DC-14	Duck	GLLA 2010-2011	11/3/2010	0-24	4.3	0.9	NA	NA	NA	NA
DC-14	Duck	GLLA 2010-2011	11/3/2010	24-48	1.8	0.7	NA	NA	NA	NA
DC-14	Duck	GLLA 2010-2011	11/3/2010	48-72	4.7	1.3	NA	NA	NA	NA
DC-14	Duck	GLLA 2010-2011	11/3/2010	72-96	6.9	1.9	NA	NA	NA	NA
DC-14	Duck	GLLA 2010-2011	11/3/2010	96-122	13.3	3.8	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	0-6	10.5	0.6	30.9	1.6	0.2	0.2
DC-16	Duck	GLLA 2010-2011	11/2/2010	0-24	5.8	1.5	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	24-48	2.4	0.7	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	48-72	1.7	0.4	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	72-96	12.8	4.1	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	96-120	9.0	3.5	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	120-144	20.3	5.6	NA	NA	NA	NA
DC-16	Duck	GLLA 2010-2011	11/2/2010	144-167	15.7	5.4	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	0-6	11.6	0.8	34.7	2.4	0.3	0.2

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
DC-17	Duck	GLLA 2010-2011	11/2/2010	0-24	7.4	2.0	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	24-48	4.0	1.2	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	48-72	2.9	1.4	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	72-96	8.8	3.6	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	96-120	15.8	5.8	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	120-144	8.7	3.1	NA	NA	NA	NA
DC-17	Duck	GLLA 2010-2011	11/2/2010	144-179	6.5	2.2	NA	NA	NA	NA
DC-19	Duck	GLLA 2010-2011	11/2/2010	0-6	1.5	0.1	4.1	0.4	0.1	0.2
DC-19	Duck	GLLA 2010-2011	11/2/2010	0-24	1.8	0.4	NA	NA	NA	NA
DC-19	Duck	GLLA 2010-2011	11/2/2010	24-48	5.5	2.2	NA	NA	NA	NA
DC-19	Duck	GLLA 2010-2011	11/2/2010	48-72	10.5	3.8	NA	NA	NA	NA
DC-19	Duck	GLLA 2010-2011	11/2/2010	72-96	18.1	4.1	NA	NA	NA	NA
DC-19	Duck	GLLA 2010-2011	11/2/2010	96-127	10.3	3.0	NA	NA	NA	NA
DC-2	Duck	GLLA 2010-2011	10/12/2010	0-24	2.4	0.8	NA	NA	NA	NA
DC-2	Duck	GLLA 2010-2011	10/12/2010	24-48	2.1	0.6	NA	NA	NA	NA
DC-20	Duck	GLLA 2010-2011	5/11/2011	0-6	38.4	0.6	120.7	1.9	0.2	0.2
DC-20	Duck	GLLA 2010-2011	5/11/2011	0-24	2.1	0.3	NA	NA	NA	NA
DC-20	Duck	GLLA 2010-2011	5/11/2011	24-36	3.8	0.3	NA	NA	NA	NA
DC-21	Duck	GLLA 2010-2011	5/11/2011	0-6	2.0	0.4	5.9	1.2	0.2	0.2
DC-21	Duck	GLLA 2010-2011	5/11/2011	0-19	1.3	0.4	NA	NA	NA	NA
DC-22	Duck	GLLA 2010-2011	5/11/2011	0-6	8.8	1.2	25.0	3.4	0.5	0.2
DC-22	Duck	GLLA 2010-2011	5/11/2011	0-24	1.0	0.2	NA	NA	NA	NA
DC-22	Duck	GLLA 2010-2011	5/11/2011	24-39	0.5	0.2	NA	NA	NA	NA
DC-23	Duck	GLLA 2010-2011	5/11/2011	0-6	4.3	0.3	12.1	0.9	0.1	0.2
DC-23	Duck	GLLA 2010-2011	5/11/2011	0-24	3.3	0.5	NA	NA	NA	NA
DC-23	Duck	GLLA 2010-2011	5/11/2011	24-48	1.3	0.5	NA	NA	NA	NA
DC-23	Duck	GLLA 2010-2011	5/11/2011	48-67	1.4	0.4	NA	NA	NA	NA
DC-24	Duck	GLLA 2010-2011	5/11/2011	0-6	27.8	1.7	69.5	4.4	0.5	0.2
DC-24	Duck	GLLA 2010-2011	5/11/2011	0-24	2.3	0.4	NA	NA	NA	NA
DC-24	Duck	GLLA 2010-2011	5/11/2011	24-53	1.4	0.1	NA	NA	NA	NA
DC-25	Duck	GLLA 2010-2011	5/11/2011	0-6	3.3	0.4	14.4	1.5	0.2	1.7
DC-25	Duck	GLLA 2010-2011	5/11/2011	0-24	1.7	0.6	NA	NA	NA	NA
DC-25	Duck	GLLA 2010-2011	5/11/2011	24-39	0.9	0.4	NA	NA	NA	NA
DC-3	Duck	GLLA 2010-2011	10/13/2010	0-6	3.9	0.5	7.3	0.9	0.1	0.3
DC-3	Duck	GLLA 2010-2011	10/13/2010	0-24	2.6	1.3	NA	NA	NA	NA
DC-3/4	Duck	GLLA 2010-2011	10/13/2010	0-6	2.0	0.4	3.9	0.8	0.1	NA
DC-3/4	Duck	GLLA 2010-2011	10/13/2010	0-24	3.7	1.9	NA	NA	NA	NA
DC-4	Duck	GLLA 2010-2011	10/13/2010	0-6	2.8	0.4	5.3	0.9	0.1	NA
DC-4	Duck	GLLA 2010-2011	10/13/2010	0-24	3.8	1.1	NA	NA	NA	NA
DC-5	Duck	GLLA 2010-2011	10/14/2010	0-6	3.1	0.6	9.3	1.9	0.3	0.2

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
DC-5	Duck	GLLA 2010-2011	10/14/2010	0-24	4.0	1.2	NA	NA	NA	NA
DC-5	Duck	GLLA 2010-2011	10/14/2010	24-48	6.7	2.4	NA	NA	NA	NA
DC-5/6	Duck	GLLA 2010-2011	10/15/2010	0-6	6.9	0.8	11.1	1.3	0.2	NA
DC-6/7	Duck	GLLA 2010-2011	10/19/2010	0-6	2.9	0.4	5.2	0.7	0.1	0.2
DC-7/8	Duck	GLLA 2010-2011	10/15/2010	0-6	1.2	0.2	2.1	0.3	0.0	NA
DC-8	Duck	GLLA 2010-2011	10/18/2010	0-24	5.0	0.9	NA	NA	NA	NA
DC-9-02	Duck	GLLA 2010-2011	10/15/2010	0-6	0.7	0.1	1.2	0.2	0.0	NA
DC-9-02	Duck	GLLA 2010-2011	10/18/2010	0-24	1.9	1.2	NA	NA	NA	NA
OC-10-11	Otter	GLLA 2010-2011	10/7/2010	0-6	1.2	0.3	2.0	0.5	0.1	NA
OC-11/12	Otter	GLLA 2010-2011	10/15/2010	0-6	33.2	3.7	262.4	29.4	3.6	NA
OC-12/13	Otter	GLLA 2010-2011	10/15/2010	0-6	0.6	0.4	1.1	0.7	0.1	0.4
OC-15/16	Otter	GLLA 2010-2011	10/19/2010	0-6	42.7	13.1	58.0	17.8	2.2	NA
OC-16	Otter	GLLA 2010-2011	10/15/2010	0-6	8.4	2.3	11.8	3.3	0.4	0.8
OC-16/17	Otter	GLLA 2010-2011	10/19/2010	0-6	25.8	8.6	35.4	11.7	1.4	NA
OC-18	Otter	GLLA 2010-2011	10/19/2010	0-24	20.1	2.5	NA	NA	NA	NA
OC-18/19	Otter	GLLA 2010-2011	10/19/2010	0-6	26.6	8.2	39.8	12.2	1.5	NA
OC-1A	Otter	GLLA 2010-2011	10/7/2010	0-6	1.0	0.3	6.3	1.7	0.2	NA
OC-1A	Otter	GLLA 2010-2011	10/4/2010	0-12	23.7	11.9	NA	NA	NA	NA
OC-1A	Otter	GLLA 2010-2011	10/4/2010	24-48	16.4	8.2	NA	NA	NA	NA
OC-2	Otter	GLLA 2010-2011	10/6/2010	0-24	4.4	1.3	NA	NA	NA	NA
OC-2	Otter	GLLA 2010-2011	10/6/2010	24-48	22.5	6.8	NA	NA	NA	NA
OC-22	Otter	GLLA 2010-2011	10/19/2010	0-6	26.4	7.0	35.6	9.4	1.1	0.4
OC-23	Otter	GLLA 2010-2011	10/19/2010	0-24	7.7	1.3	NA	NA	NA	NA
OC-23	Otter	GLLA 2010-2011	10/19/2010	24-48	15.2	6.3	NA	NA	NA	NA
OC-24/25	Otter	GLLA 2010-2011	10/19/2010	0-6	0.9	0.5	2.3	1.3	0.2	0.2
OC-26	Otter	GLLA 2010-2011	11/3/2010	0-6	40.7	16.5	263.5	106.7	14.9	27.6
OC-26	Otter	GLLA 2010-2011	11/3/2010	0-24	5.2	3.0	NA	NA	NA	NA
OC-26	Otter	GLLA 2010-2011	11/3/2010	24-49	1.3	1.6	NA	NA	NA	NA
OC-27	Otter	GLLA 2010-2011	11/3/2010	0-6	8.4	2.4	187.3	54.0	7.2	31.5
OC-27	Otter	GLLA 2010-2011	11/3/2010	0-24	4.0	2.3	NA	NA	NA	NA
OC-27	Otter	GLLA 2010-2011	11/3/2010	24-50	0.4	0.4	NA	NA	NA	NA
OC-28	Otter	GLLA 2010-2011	11/3/2010	0-6	13.2	2.3	53.4	9.4	1.2	15.7
OC-28	Otter	GLLA 2010-2011	11/3/2010	0-24	18.3	2.2	NA	NA	NA	NA
OC-28	Otter	GLLA 2010-2011	11/3/2010	24-48	2.4	4.4	NA	NA	NA	NA
OC-28	Otter	GLLA 2010-2011	11/3/2010	48-52	0.1	0.2	NA	NA	NA	NA
OC-29	Otter	GLLA 2010-2011	11/4/2010	0-6	31.7	10.4	101.8	33.4	4.3	26.4
OC-29	Otter	GLLA 2010-2011	11/4/2010	0-24	16.7	8.0	NA	NA	NA	NA
OC-29	Otter	GLLA 2010-2011	11/4/2010	24-52	2.6	2.8	NA	NA	NA	NA
OC-2A	Otter	GLLA 2010-2011	10/7/2010	0-6	1.1	0.3	4.3	1.1	0.1	NA
OC-2A	Otter	GLLA 2010-2011	10/6/2010	0-24	5.4	1.4	NA	NA	NA	NA

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
OC-2A	Otter	GLLA 2010-2011	10/6/2010	24-48	8.5	4.3	NA	NA	NA	NA
OC-2A	Otter	GLLA 2010-2011	10/6/2010	48-72	4.5	0.5	NA	NA	NA	NA
OC-3	Otter	GLLA 2010-2011	10/7/2010	0-24	9.6	1.8	NA	NA	NA	NA
OC-3	Otter	GLLA 2010-2011	10/7/2010	24-48	2.7	0.5	NA	NA	NA	NA
OC-30	Otter	GLLA 2010-2011	11/4/2010	0-6	18.2	7.6	100.2	41.9	5.6	10.5
OC-30	Otter	GLLA 2010-2011	11/4/2010	0-24	13.4	9.5	NA	NA	NA	NA
OC-30	Otter	GLLA 2010-2011	11/4/2010	24-42	1.4	2.8	NA	NA	NA	NA
OC-31	Otter	GLLA 2010-2011	11/4/2010	0-6	1.2	0.7	3.4	1.9	0.3	0.4
OC-31	Otter	GLLA 2010-2011	11/4/2010	0-24	1.3	2.4	NA	NA	NA	NA
OC-31	Otter	GLLA 2010-2011	11/4/2010	24-48	12.8	11.7	NA	NA	NA	NA
OC-32	Otter	GLLA 2010-2011	11/4/2010	0-6	6.2	1.7	24.5	6.7	0.9	7.6
OC-32	Otter	GLLA 2010-2011	11/4/2010	0-24	23.5	18.2	NA	NA	NA	NA
OC-32	Otter	GLLA 2010-2011	11/4/2010	24-30	1.2	2.7	NA	NA	NA	NA
OC-33	Otter	GLLA 2010-2011	11/4/2010	0-6	0.9	0.5	2.1	1.1	0.2	0.2
OC-33	Otter	GLLA 2010-2011	11/4/2010	0-24	4.0	2.4	NA	NA	NA	NA
OC-33	Otter	GLLA 2010-2011	11/4/2010	24-39	1.0	2.1	NA	NA	NA	NA
OC-34	Otter	GLLA 2010-2011	5/10/2011	0-6	1.5	1.2	10.5	8.3	1.2	0.2
OC-34	Otter	GLLA 2010-2011	5/10/2011	0-29	12.3	5.8	NA	NA	NA	NA
OC-35	Otter	GLLA 2010-2011	5/12/2011	0-6	2.7	0.5	9.8	1.8	0.2	1.8
OC-35	Otter	GLLA 2010-2011	5/12/2011	0-24	3.8	1.4	NA	NA	NA	NA
OC-36	Otter	GLLA 2010-2011	5/10/2011	0-6	0.8	0.2	3.4	0.9	0.1	0.5
OC-36	Otter	GLLA 2010-2011	5/10/2011	0-15	0.0	0.0	NA	NA	NA	NA
OC-38	Otter	GLLA 2010-2011	5/11/2011	0-6	0.2	0.1	1.3	0.6	0.1	0.2
OC-3A	Otter	GLLA 2010-2011	10/7/2010	0-6	0.4	0.2	4.2	1.9	0.3	NA
OC-3A	Otter	GLLA 2010-2011	10/7/2010	0-24	4.3	1.1	NA	NA	NA	NA
OC-3A	Otter	GLLA 2010-2011	10/7/2010	24-48	4.2	0.5	NA	NA	NA	NA
OC-4	Otter	GLLA 2010-2011	10/7/2010	0-6	1.1	0.2	8.6	1.7	0.2	18.1
OC-4	Otter	GLLA 2010-2011	10/7/2010	0-24	3.9	1.0	NA	NA	NA	NA
OC-4	Otter	GLLA 2010-2011	10/7/2010	24-48	3.4	0.6	NA	NA	NA	NA
OC-40	Otter	GLLA 2010-2011	5/11/2011[b]	0-6	0.4	0.3	1.8	1.3	0.2	0.2
OC-40	Otter	GLLA 2010-2011	5/11/2011	0-23	1.2	1.4	NA	NA	NA	NA
OC-41	Otter	GLLA 2010-2011	5/10/2011	0-6	0.6	0.6	2.2	2.2	0.3	0.2
OC-41	Otter	GLLA 2010-2011	5/10/2011	0-23	0.3	0.3	NA	NA	NA	NA
OC-42	Otter	GLLA 2010-2011	5/11/2011	0-6	34.6	7.6	157.3	34.7	4.8	169.8
OC-42	Otter	GLLA 2010-2011	5/11/2011	0-23	2.6	1.6	NA	NA	NA	NA
OC-44	Otter	GLLA 2010-2011	5/10/2011	0-6	55.6	7.7	396.8	54.8	7.8	61.5
OC-44	Otter	GLLA 2010-2011	5/10/2011	0-27	166.7	16.3	NA	NA	NA	NA
OC-45	Otter	GLLA 2010-2011	5/10/2011	0-6	3.1	0.8	12.5	3.4	0.5	87.2
OC-45	Otter	GLLA 2010-2011	5/10/2011	0-25	48.7	11.0	NA	NA	NA	NA
OC-46	Otter	GLLA 2010-2011	5/12/2011	0-6	0.5	0.2	1.0	0.4	0.1	0.6

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
OC-46	Otter	GLLA 2010-2011	5/12/2011	0-24	1.8	0.8	NA	NA	NA	NA
OC-47	Otter	GLLA 2010-2011	5/12/2011	0-6	0.8	0.4	1.1	0.5	0.1	0.3
OC-47	Otter	GLLA 2010-2011	5/12/2011	0-24	0.7	0.3	NA	NA	NA	NA
OC-47	Otter	GLLA 2010-2011	5/12/2011	24-48	0.8	0.4	NA	NA	NA	NA
OC-47	Otter	GLLA 2010-2011	5/12/2011	48-62	1.0	0.5	NA	NA	NA	NA
OC-48	Otter	GLLA 2010-2011	5/12/2011	0-6	1.4	0.7	2.3	1.1	0.1	0.3
OC-48	Otter	GLLA 2010-2011	5/12/2011	0-24	0.3	0.1	NA	NA	NA	NA
OC-48	Otter	GLLA 2010-2011	5/12/2011	24-48	1.7	0.8	NA	NA	NA	NA
OC-48	Otter	GLLA 2010-2011	5/12/2011	48-60	1.7	0.7	NA	NA	NA	NA
OC-49	Otter	GLLA 2010-2011	10/18/2011	0-6	3.3	0.9	9.8	2.8	0.4	67.7
OC-49	Otter	GLLA 2010-2011	10/18/2011	0-24	5.3	3.5	NA	NA	NA	NA
OC-49	Otter	GLLA 2010-2011	10/18/2011	24-48	1.0	1.2	NA	NA	NA	NA
OC-4A	Otter	GLLA 2010-2011	10/7/2010	0-6	1.2	0.3	2.9	0.9	0.1	NA
OC-4A	Otter	GLLA 2010-2011	10/7/2010	0-24	4.1	1.2	NA	NA	NA	NA
OC-4A	Otter	GLLA 2010-2011	10/7/2010	24-48	4.0	1.0	NA	NA	NA	NA
OC-5	Otter	GLLA 2010-2011	10/8/2010	0-24	3.9	3.5	NA	NA	NA	NA
OC-5	Otter	GLLA 2010-2011	10/8/2010	24-48	5.2	1.2	NA	NA	NA	NA
OC-50	Otter	GLLA 2010-2011	10/18/2011	0-6	1.2	0.4	4.7	1.6	0.2	133.6
OC-50	Otter	GLLA 2010-2011	10/18/2011	0-24	2.1	0.7	NA	NA	NA	NA
OC-50	Otter	GLLA 2010-2011	10/18/2011	24-48	1.0	1.2	NA	NA	NA	NA
OC-50	Otter	GLLA 2010-2011	10/18/2011	48-63	1.0	1.0	NA	NA	NA	NA
OC-51	Otter	GLLA 2010-2011	10/18/2011	0-6	0.2	0.1	0.5	0.2	0.0	5.2
OC-51	Otter	GLLA 2010-2011	10/18/2011	0-24	1.1	0.8	NA	NA	NA	NA
OC-51	Otter	GLLA 2010-2011	10/18/2011	24-48	1.0	1.6	NA	NA	NA	NA
OC-52	Otter	GLLA 2010-2011	10/18/2011	0-6	0.8	0.1	3.8	0.6	0.1	58.2
OC-52	Otter	GLLA 2010-2011	10/18/2011	0-24	2.1	0.5	NA	NA	NA	NA
OC-52	Otter	GLLA 2010-2011	10/18/2011	24-48	1.9	0.6	NA	NA	NA	NA
OC-52	Otter	GLLA 2010-2011	10/18/2011	48-64	1.0	1.5	NA	NA	NA	NA
OC-53	Otter	GLLA 2010-2011	10/18/2011	0-6	0.8	0.4	2.1	1.0	0.1	2.9
OC-53	Otter	GLLA 2010-2011	10/18/2011	0-24	1.2	1.0	NA	NA	NA	NA
OC-53	Otter	GLLA 2010-2011	10/18/2011	24-32	1.1	1.0	NA	NA	NA	NA
OC-54	Otter	GLLA 2010-2011	10/18/2011	0-6	1.5	0.5	5.1	1.7	0.2	7.7
OC-54	Otter	GLLA 2010-2011	10/18/2011	0-24	2.5	0.7	NA	NA	NA	NA
OC-54	Otter	GLLA 2010-2011	10/18/2011	24-48	45.0	10.5	NA	NA	NA	NA
OC-54	Otter	GLLA 2010-2011	10/18/2011	48-65	34.3	8.9	NA	NA	NA	NA
OC-55	Otter	GLLA 2010-2011	10/18/2011	0-6	0.2	0.1	0.5	0.2	0.0	1.0
OC-55	Otter	GLLA 2010-2011	10/18/2011	0-24	1.6	1.0	NA	NA	NA	NA
OC-55	Otter	GLLA 2010-2011	10/18/2011	24-42	1.2	0.4	NA	NA	NA	NA
OC-56	Otter	GLLA 2010-2011	10/18/2011	0-6	6.7	1.8	43.9	11.9	1.8	70.7
OC-56	Otter	GLLA 2010-2011	10/18/2011	0-24	3.7	1.0	NA	NA	NA	NA

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
OC-56	Otter	GLLA 2010-2011	10/18/2011	24-48	4.0	1.5	NA	NA	NA	NA
OC-56	Otter	GLLA 2010-2011	10/18/2011	48-72	4.3	2.6	NA	NA	NA	NA
OC-56	Otter	GLLA 2010-2011	10/18/2011	72-96	2.5	0.9	NA	NA	NA	NA
OC-56	Otter	GLLA 2010-2011	10/18/2011	96-112	1.7	1.1	NA	NA	NA	NA
OC-57	Otter	GLLA 2010-2011	10/18/2011	0-6	3.7	0.8	17.3	4.0	0.5	8.7
OC-57	Otter	GLLA 2010-2011	10/18/2011	0-24	1.5	0.5	NA	NA	NA	NA
OC-57	Otter	GLLA 2010-2011	10/18/2011	24-48	15.7	3.3	NA	NA	NA	NA
OC-57	Otter	GLLA 2010-2011	10/18/2011	48-72	6.6	1.3	NA	NA	NA	NA
OC-57	Otter	GLLA 2010-2011	10/18/2011	72-96	2.4	0.6	NA	NA	NA	NA
OC-57	Otter	GLLA 2010-2011	10/18/2011	96-112	5.4	1.7	NA	NA	NA	NA
OC-58	Otter	GLLA 2010-2011	10/18/2011	0-6	0.2	0.1	0.4	0.2	0.0	0.4
OC-58	Otter	GLLA 2010-2011	10/18/2011	0-24	1.4	0.5	NA	NA	NA	NA
OC-58	Otter	GLLA 2010-2011	10/18/2011	24-48	1.6	0.6	NA	NA	NA	NA
OC-58	Otter	GLLA 2010-2011	10/18/2011	48-72	1.4	0.4	NA	NA	NA	NA
OC-58	Otter	GLLA 2010-2011	10/18/2011	72-96	1.4	0.5	NA	NA	NA	NA
OC-58	Otter	GLLA 2010-2011	10/18/2011	96-121	1.4	0.5	NA	NA	NA	NA
OC-59	Otter	GLLA 2010-2011	10/18/2011	0-6	0.2	0.1	0.6	0.2	0.0	0.4
OC-59	Otter	GLLA 2010-2011	10/18/2011	0-24	1.2	0.4	NA	NA	NA	NA
OC-59	Otter	GLLA 2010-2011	10/18/2011	24-48	2.8	1.1	NA	NA	NA	NA
OC-59	Otter	GLLA 2010-2011	10/18/2011	48-72	4.9	1.5	NA	NA	NA	NA
OC-59	Otter	GLLA 2010-2011	10/18/2011	72-96	1.4	0.3	NA	NA	NA	NA
OC-59	Otter	GLLA 2010-2011	10/18/2011	96-121	2.0	0.5	NA	NA	NA	NA
OC-5A	Otter	GLLA 2010-2011	10/8/2010	0-6	0.5	0.1	2.8	0.9	0.1	6.6
OC-5a	Otter	GLLA 2010-2011	10/8/2010	0-24	3.8	1.6	NA	NA	NA	NA
OC-5a	Otter	GLLA 2010-2011	10/8/2010	24-48	3.2	0.5	NA	NA	NA	NA
OC-6	Otter	GLLA 2010-2011	10/11/2010	0-24	3.8	0.7	NA	NA	NA	NA
OC-6	Otter	GLLA 2010-2011	10/11/2010	24-48	3.0	0.4	NA	NA	NA	NA
OC-6/7(1)	Otter	GLLA 2010-2011	10/11/2010	0-6	1.7	0.9	5.0	2.6	0.3	NA
OC-6/7(1)	Otter	GLLA 2010-2011	10/11/2010	0-24	2.6	0.4	NA	NA	NA	NA
OC-6/7(1)	Otter	GLLA 2010-2011	10/11/2010	24-48	2.7	0.9	NA	NA	NA	NA
OC-6/7(2)	Otter	GLLA 2010-2011	10/11/2010	0-6	1.4	0.4	6.4	1.6	0.2	4.1
OC-6/7(2)	Otter	GLLA 2010-2011	10/11/2010	0-24	2.6	0.6	NA	NA	NA	NA
OC-60	Otter	GLLA 2010-2011	10/18/2011	0-6	9.8	1.8	20.6	3.7	0.5	5.7
OC-60	Otter	GLLA 2010-2011	10/18/2011	0-24	3.0	0.7	NA	NA	NA	NA
OC-60	Otter	GLLA 2010-2011	10/18/2011	24-48	15.9	3.2	NA	NA	NA	NA
OC-60	Otter	GLLA 2010-2011	10/18/2011	48-72	18.9	3.1	NA	NA	NA	NA
OC-60	Otter	GLLA 2010-2011	10/18/2011	72-96	12.5	2.1	NA	NA	NA	NA
OC-60	Otter	GLLA 2010-2011	10/18/2011	96-121	3.5	0.7	NA	NA	NA	NA
OC-61	Otter	GLLA 2010-2011	10/18/2011	0-6	0.5	0.2	0.7	0.3	0.0	0.4
OC-61	Otter	GLLA 2010-2011	10/18/2011	0-24	1.6	0.6	NA	NA	NA	NA

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
OC-61	Otter	GLLA 2010-2011	10/18/2011	24-48	1.6	0.6	NA	NA	NA	NA
OC-61	Otter	GLLA 2010-2011	10/18/2011	48-72	1.5	0.5	NA	NA	NA	NA
OC-61	Otter	GLLA 2010-2011	10/18/2011	72-96	4.3	1.2	NA	NA	NA	NA
OC-61	Otter	GLLA 2010-2011	10/18/2011	96-122	7.3	1.9	NA	NA	NA	NA
OC-7-8	Otter	GLLA 2010-2011	10/7/2010	0-6	1.5	0.5	2.9	0.9	0.1	NA
OC-8	Otter	GLLA 2010-2011	10/12/2010	0-24	2.5	0.7	NA	NA	NA	NA
OC-8-9	Otter	GLLA 2010-2011	10/7/2010	0-6	0.9	0.3	5.7	1.9	0.2	NA
OC-9-10	Otter	GLLA 2010-2011	10/7/2010	0-6	1.5	0.3	3.7	0.8	0.1	4.4
DC-SED-01	Duck	GLNPO 2007	4/7/2007	NA	5.8	2.9	18.9	9.4	1.3	NA
DC-SED-03	Duck	GLNPO 2007	4/7/2007	NA	9.3	4.7	13.7	6.8	0.9	NA
DC-SED-05	Duck	GLNPO 2007	4/7/2007	NA	8.0	4.0	16.7	8.4	1.1	NA
DC-SED-08	Duck	GLNPO 2007	4/2/2007	NA	17.1	0.5	NA	NA	NA	NA
DC-SED-08	Duck	GLNPO 2007	4/7/2007	NA	20.3	0.6	26.2	0.8	0.1	NA
DC-SED-10	Duck	GLNPO 2007	4/3/2007	NA	10.5	0.8	NA	NA	NA	NA
DC-SED-10	Duck	GLNPO 2007	4/7/2007	NA	16.7	1.2	21.2	1.6	0.2	NA
DC-SED-13	Duck	GLNPO 2007	4/7/2007	NA	25.7	12.8	36.3	18.1	2.3	NA
DC-SED-14	Duck	GLNPO 2007	4/4/2007	NA	897.0	186.1	NA	NA	NA	NA
DC-SED-14	Duck	GLNPO 2007	4/4/2007	NA	2.8	0.6	NA	NA	NA	NA
DC-SED-14	Duck	GLNPO 2007	4/7/2007	NA	1933.5	401.1	2385.5	494.8	63.3	NA
OC-SED-01	Otter	GLNPO 2007	4/2/2007	NA	8.8	3.9	NA	NA	NA	NA
OC-SED-01	Otter	GLNPO 2007	4/7/2007	NA	14.9	6.7	48.1	21.5	2.7	NA
OC-SED-03	Otter	GLNPO 2007	4/2/2007	NA	12.8	1.2	NA	NA	NA	NA
OC-SED-03	Otter	GLNPO 2007	4/2/2007	NA	10.4	1.0	NA	NA	NA	NA
OC-SED-03	Otter	GLNPO 2007	4/7/2007	NA	34.6	3.2	108.2	9.9	1.2	NA
OC-SED-05	Otter	GLNPO 2007	4/2/2007	NA	16.1	1.1	NA	NA	NA	NA
OC-SED-05	Otter	GLNPO 2007	4/7/2007	NA	21.5	1.4	53.9	3.5	0.5	NA
OC-SED-07	Otter	GLNPO 2007	4/7/2007	NA	22.2	11.1	98.3	49.1	6.1	NA
OC-SED-11	Otter	GLNPO 2007	4/3/2007	NA	28.5	2.4	NA	NA	NA	NA
OC-SED-11	Otter	GLNPO 2007	4/7/2007	NA	33.8	2.8	59.8	5.0	0.6	NA
OC-SED-14	Otter	GLNPO 2007	4/3/2007	NA	20.6	5.4	NA	NA	NA	NA
OC-SED-14	Otter	GLNPO 2007	4/3/2007	NA	17.4	4.6	NA	NA	NA	NA
OC-SED-14	Otter	GLNPO 2007	4/7/2007	NA	24.4	6.5	36.8	9.7	1.2	NA
OC-SED-19	Otter	GLNPO 2007	4/3/2007	NA	15.2	8.5	NA	NA	NA	NA
OC-SED-19	Otter	GLNPO 2007	4/7/2007	NA	28.8	16.1	37.7	21.0	2.7	NA
OC-SED-22	Otter	GLNPO 2007	4/3/2007	NA	248.8	47.6	NA	NA	NA	NA
OC-SED-22	Otter	GLNPO 2007	4/3/2007	NA	7.7	1.5	NA	NA	NA	NA
OC-SED-22	Otter	GLNPO 2007	4/7/2007	NA	242.7	46.5	294.4	56.4	7.0	NA
OC-SED-26	Otter	GLNPO 2007	4/2/2007	NA	3.2	0.3	NA	NA	NA	NA
OC-SED-26	Otter	GLNPO 2007	4/7/2007	NA	24.5	2.2	29.9	2.7	0.3	NA
S02-DC-02	Duck	GLNPO 2007	4/2/2007	NA	9.3	1.3	NA	NA	NA	NA

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)
S02-DC-02	Duck	GLNPO 2007	4/2/2007	NA	5.7	0.8	NA	NA	NA	NA
S04-DC-04	Duck	GLNPO 2007	4/2/2007	NA	8.3	0.4	NA	NA	NA	NA
S04-DC-04	Duck	GLNPO 2007	4/3/2007	NA	7.4	0.2	NA	NA	NA	NA
S06-DC-06	Duck	GLNPO 2007	4/3/2007	NA	15.3	0.9	NA	NA	NA	NA
S07-DC-07	Duck	GLNPO 2007	4/2/2007	NA	15.7	0.3	NA	NA	NA	NA
S09-DC-09	Duck	GLNPO 2007	4/2/2007	NA	13.6	0.2	NA	NA	NA	NA
S11-DC-11	Duck	GLNPO 2007	4/3/2007	NA	10.8	0.4	NA	NA	NA	NA
S12-DC-12	Duck	GLNPO 2007	4/3/2007	NA	18.4	0.7	NA	NA	NA	NA
S12-DC-12	Duck	GLNPO 2007	4/4/2007	NA	56.4	6.3	NA	NA	NA	NA
S16-DC-16	Duck	GLNPO 2007	4/2/2007	NA	20.9	1.9	NA	NA	NA	NA
S17-DC-17	Duck	GLNPO 2007	4/2/2007	NA	13.6	1.0	NA	NA	NA	NA
S18-DC-18	Duck	GLNPO 2007	4/2/2007	NA	13.2	1.7	NA	NA	NA	NA
S18-DC-18	Duck	GLNPO 2007	4/4/2007	NA	3.1	0.7	NA	NA	NA	NA
S21-OC-02	Otter	GLNPO 2007	4/2/2007	NA	15.8	1.0	NA	NA	NA	NA
S25-OC-06	Otter	GLNPO 2007	4/2/2007	NA	5.7	0.6	NA	NA	NA	NA
S26-OC-07	Otter	GLNPO 2007	4/3/2007	NA	11.2	0.8	NA	NA	NA	NA
S27-OC-08	Otter	GLNPO 2007	4/3/2007	NA	9.9	2.0	NA	NA	NA	NA
S27-OC-08	Otter	GLNPO 2007	4/4/2007	NA	107.5	29.0	NA	NA	NA	NA
S29-OC-10	Otter	GLNPO 2007	4/4/2007	NA	16.0	0.9	NA	NA	NA	NA
S31-OC-12	Otter	GLNPO 2007	4/3/2007	NA	21.7	4.5	NA	NA	NA	NA
S31-OC-12	Otter	GLNPO 2007	4/3/2007	NA	13.7	2.9	NA	NA	NA	NA
S35-OC-16	Otter	GLNPO 2007	4/3/2007	NA	36.8	5.6	NA	NA	NA	NA
S36-OC-17	Otter	GLNPO 2007	4/3/2007	NA	100.6	14.7	NA	NA	NA	NA
S36-OC-17	Otter	GLNPO 2007	4/3/2007	NA	48.4	7.1	NA	NA	NA	NA
S39-OC-20	Otter	GLNPO 2007	4/3/2007	NA	92.5	23.8	NA	NA	NA	NA
S39-OC-20	Otter	GLNPO 2007	4/3/2007	NA	21.8	5.6	NA	NA	NA	NA
S41-OC-21A	Otter	GLNPO 2007	4/4/2007	NA	10.3	1.7	NA	NA	NA	NA
S44-OC-24	Otter	GLNPO 2007	4/3/2007	NA	5.7	2.2	NA	NA	NA	NA
S45-OC-25	Otter	GLNPO 2007	4/3/2007	NA	9.5	2.1	NA	NA	NA	NA
S45-OC-25	Otter	GLNPO 2007	4/3/2007	NA	21.8	4.9	NA	NA	NA	NA
Millard Road	Otter	OEPA 2006	10/11/2006	NA	20.7	5.3	NA	NA	NA	NA
Oakdale Avenue	Otter	OEPA 2006	10/4/2006	NA	52.0	11.3	NA	NA	NA	NA
Yarrow Street/Consaul Street	Otter	OEPA 2006	10/11/2006	NA	36.9	5.1	NA	NA	NA	NA
300376	Duck	OEPA 2008	10/2/2008	NA	90.7	45.4	NA	NA	NA	NA
P11K22	Duck	OEPA 2008	10/2/2008	NA	56.7	28.3	NA	NA	NA	NA
P11S56	Duck	OEPA 2008	10/2/2008	NA	80.1	40.0	NA	NA	NA	NA
WLF-SD-01	Otter	WLF 2009	8/20/2009	NA	12.3	6.2	NA	NA	NA	NA
WLF-SD-02	Otter	WLF 2009	8/20/2009	NA	35.3	17.7	NA	NA	NA	NA

Attachment 1B: PAH Calculation Results

Location	Creek	Event	Date Sampled	Depth (inches)	Total PAH-16 (mg/kg)	Total PAH-16 (mg/kg at 1% TOC)	Total PAHs-34[a] (mg/kg)	Total PAHs-34[a] (mg/kg at 1% TOC)	ESBTU (unitless)	Porewater PAH Toxic Units (unitless)

a. 33 PAHs were analyzed in the Envirosafe 2006-2007 sampling event.
b. Location OC-40: porewater PAHs for PWPAHTU calculation were sampled on 5/10/2011.
ESBTU: equilibrium partitioning sediment benchmark toxic units
mg/kg: milligrams per kilogram
NA: not available (for depth) or not analyzed
PAH: polycyclic aromatic hydrocarbons
TOC: total organic carbon

Attachment 1C. Qualifier Definitions

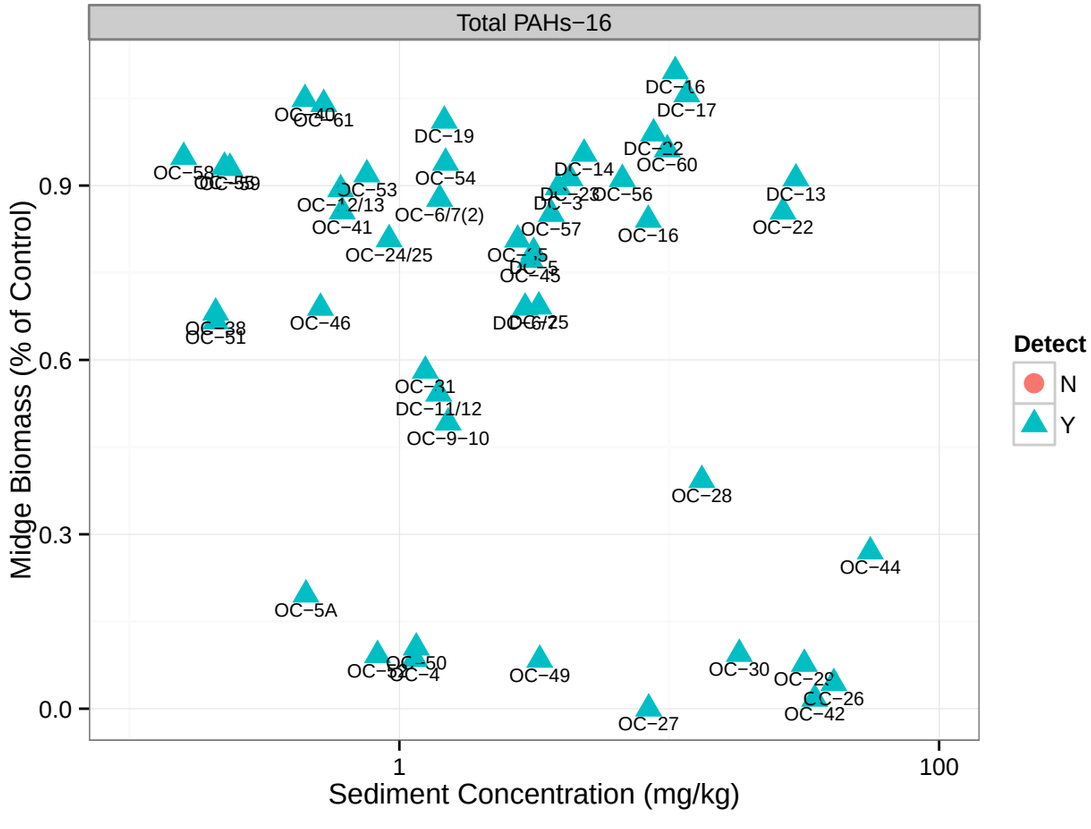
Event	Qualifier	Description	Chemical Type
GLLA 2010-2011	-	Qualifier definition not determined	Not Specified
GLLA 2010-2011	+	Qualifier definition not determined	Not Specified
GLLA 2010-2011	B	This flag is used when the analyte is found in the associated blank, as well as in the sample.	Organics
GLNPO 2007	B	Analyte detected in laboratory method blank	Inorganics
GLNPO 2007	CV	Estimated value; calibration verification results exceed upper or lower control limits.	Organics
GLLA 2010-2011	D	The reported value is from a dilution	All
GLLA 2010-2011	E	The reported value is estimated due to the presence of interference.	Inorganics
GLLA 2010-2011	E	This flag identifies compounds whose response exceed the response of the highest standard in the initial calibration range of the instrument for that specific analysis.	Organics
GLLA 2010-2011	E	This flag identifies analytes whose concentrations exceed the calibration range of the HRGC/HRMS instrument for that specific analysis.	PCB Congeners, Dioxins and Furans
GLNPO 2007	F	Qualifier definition not determined	Not Specified
GLNPO 2007	H	Estimated value; holding time exceeded	Organics
GLNPO 2007	IS	Estimated value; internal standard recoveries are outside the upper or lower control limits	Organics
Envirosafe 2006-2007	J	Estimated value	Not Specified
GLLA 2010-2011; GLNPO 2007	J	Estimated value; greater than detection limit, but less than reporting limit	Inorganics
GLLA 2010-2011	J	Indicates an estimated value.	Organics
GLNPO 2007	J	Estimated value; greater than detection limit, but less than reporting limit	Organics
OEPA 2006, 2008; WLF 2009	J	Estimated value	Not Specified
GLNPO 2007	LC	Estimated value; laboratory control recoveries exceed upper or lower control limits.	Organics
GLNPO 2007	LD	Estimated value; batch quality control for laboratory duplicate exceeds upper or lower control limits	Inorganics
GLNPO 2007	LS	Estimated value; batch quality control for laboratory surrogate exceeds upper or lower control limits.	Organics
GLNPO 2007	M	Estimated value; associated MS/MSD recoveries exceed the upper or lower control limits	Inorganics
GLNPO 2007	MS	Estimated value; relative percent difference (RPD) between MS/MSD exceeded specified criteria	All
GLLA 2010-2011, OEPA 2006	N	Tentatively identified compound	Not Specified
GLLA 2010-2011	P	This flag is used for pesticide and Aroclor target compounds when there is greater than 25% difference for detected concentrations between the two GC columns (see Form X).	Organics

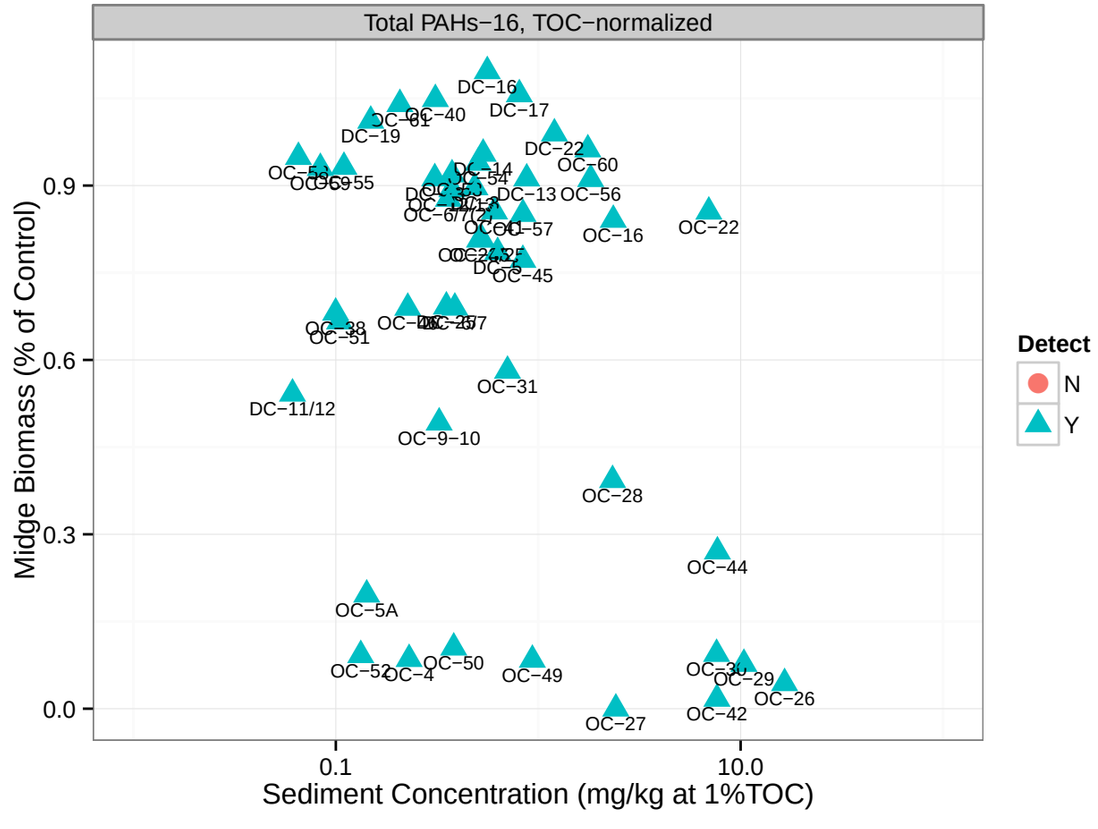
Attachment 1C. Qualifier Definitions

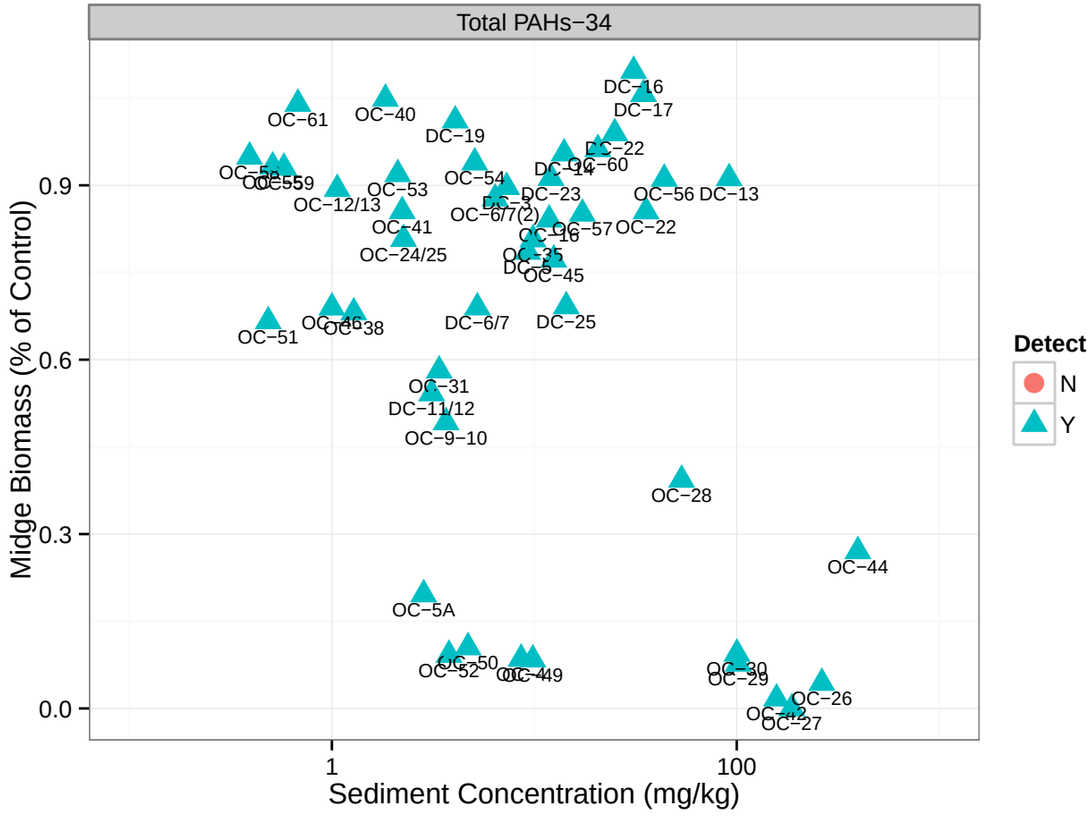
Event	Qualifier	Description	Chemical Type
OEPA 2006	P	Difference in results between two detectors exceeds performance limit.	Not Specified
Envirosafe 2006-2007; GLLA 2010-2011; GLNPO 2007; OEPA 2006	R	Result is rejected	Not Specified
GLNPO 2007	SD	Estimated value; serial dilution exceeds specified criteria	Inorganics
All	U	Analyte not detected	All
GLLA 2010-2011	V1	Qualifier definition not determined	Not Specified

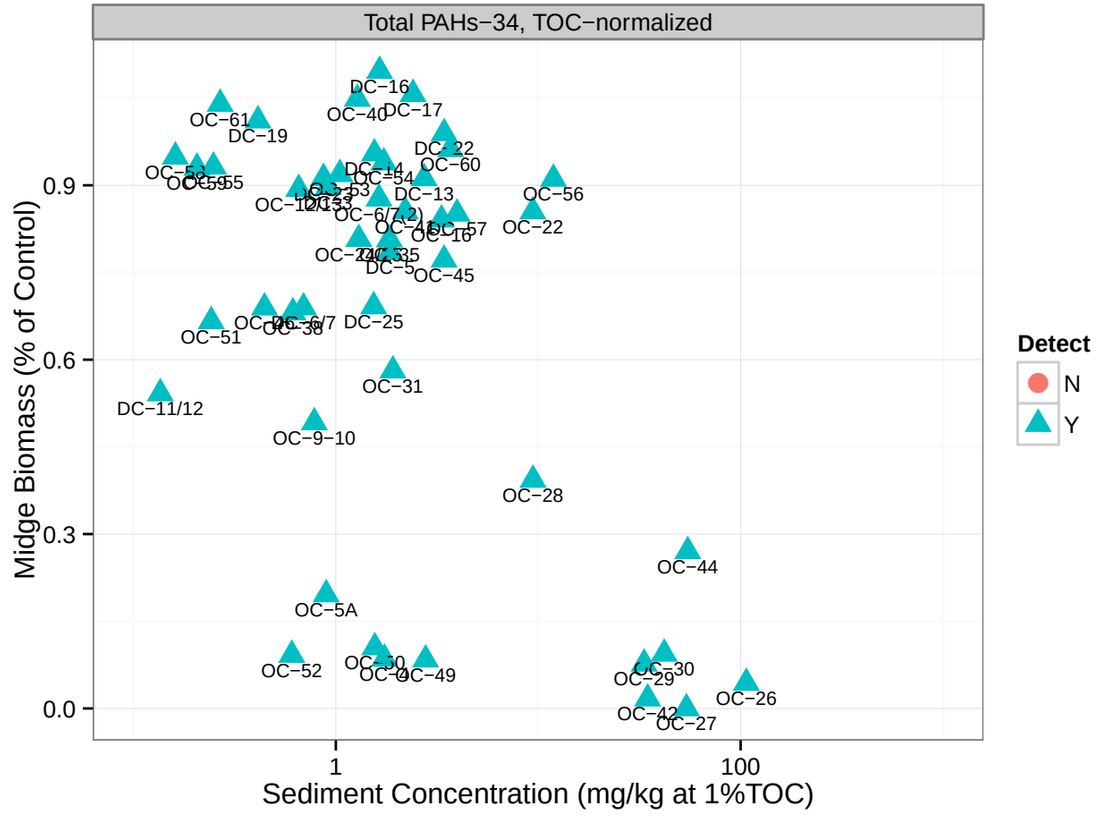
Attachment 2

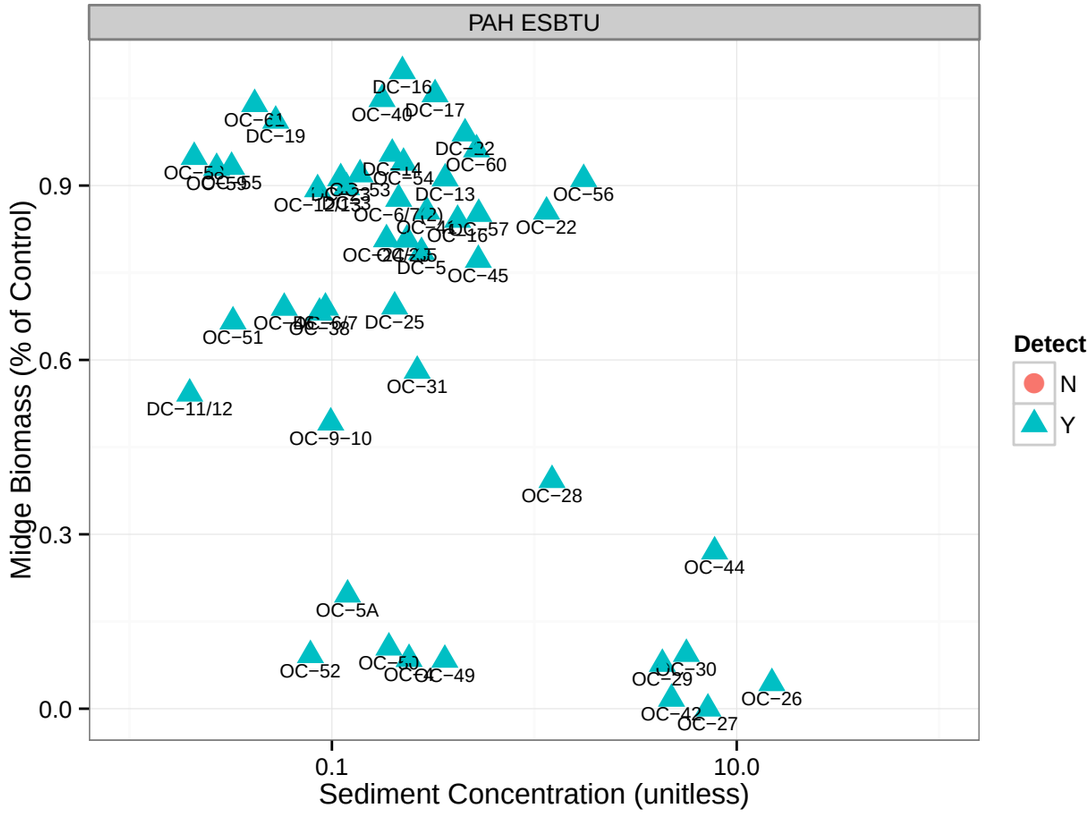
Graphs of Analytical Parameters versus Midge Biomass

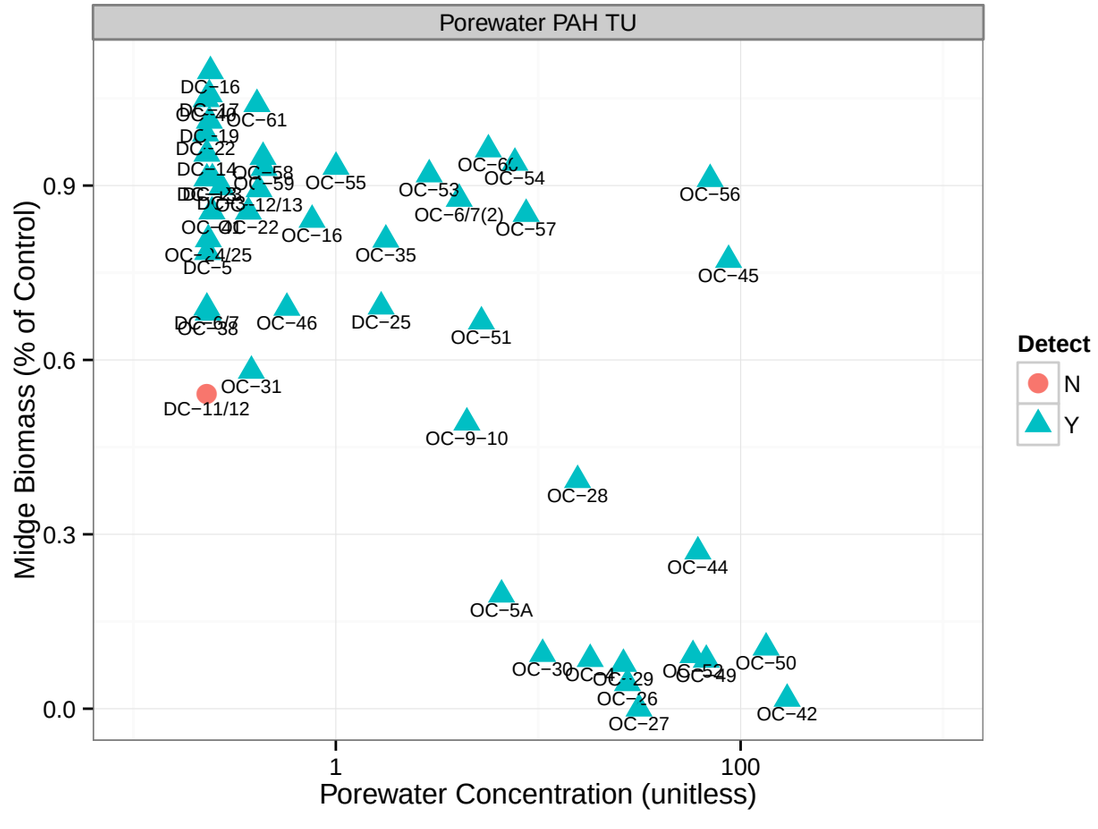

Total PAHs−16
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
100
Sediment Concentration (mg/kg)
Detect
N
Y

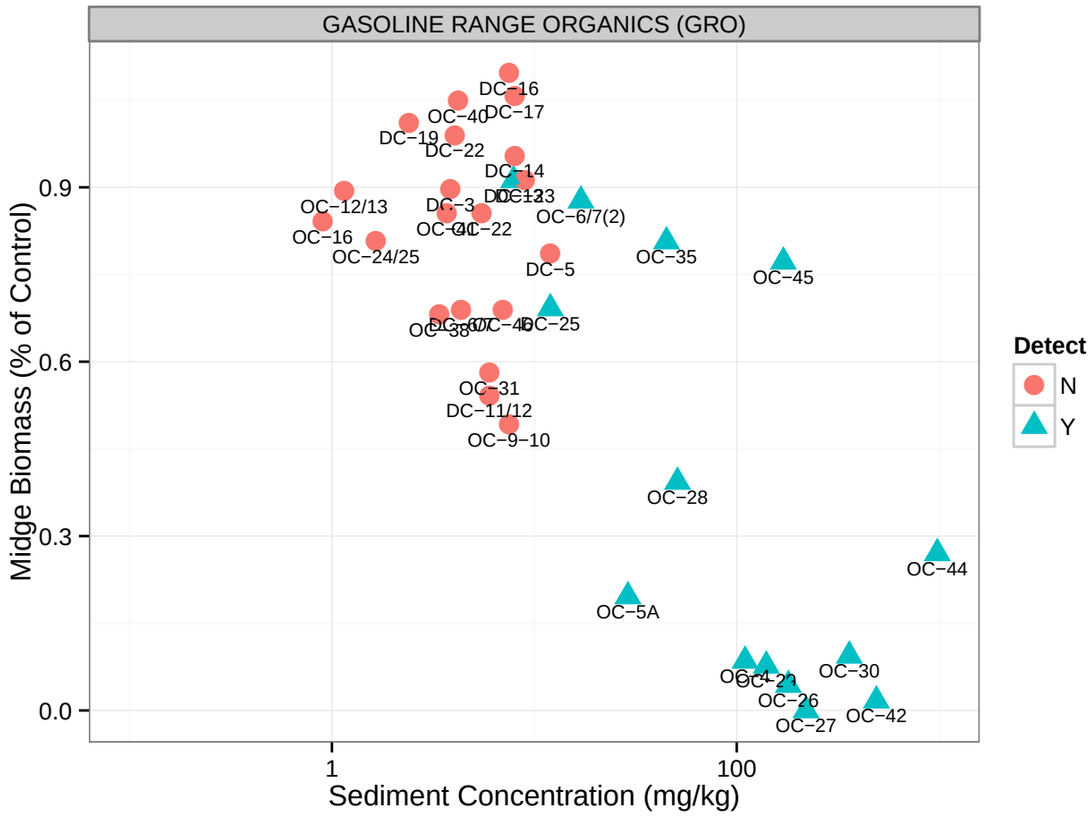

Total PAHs−16, TOC−normalized
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
10.0
Sediment Concentration (mg/kg at 1%TOC)
Detect
N
Y

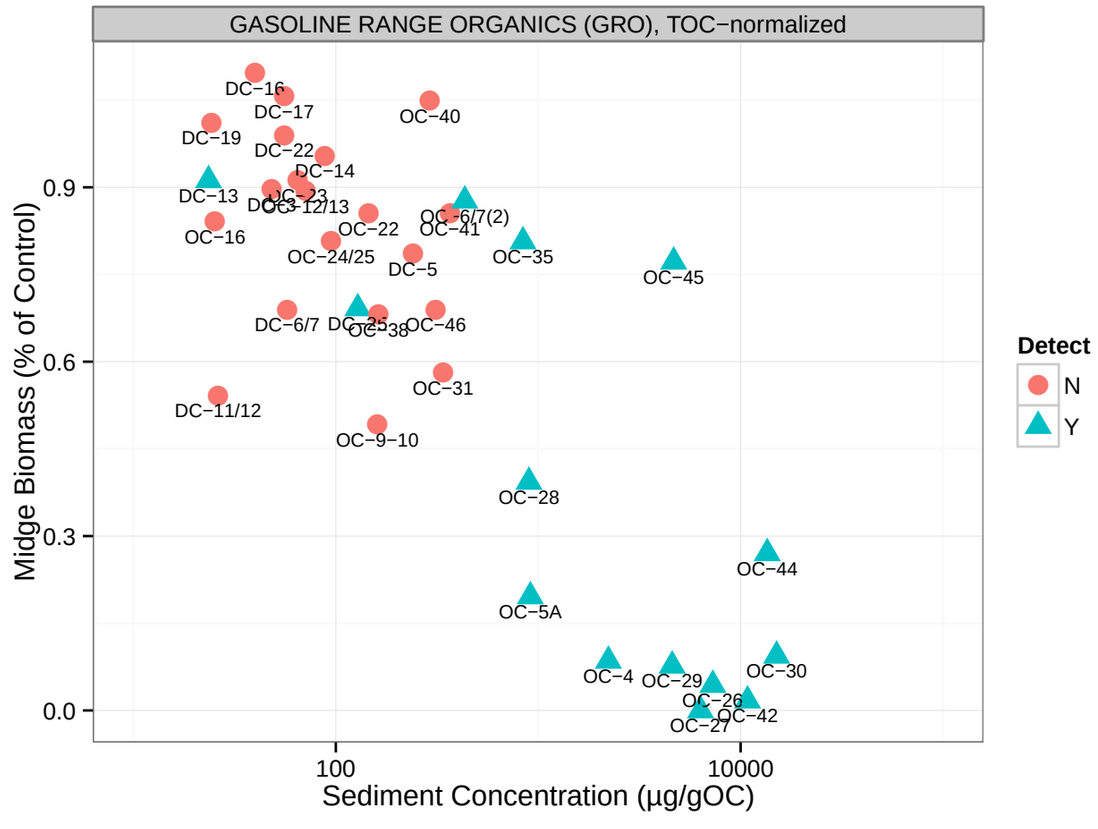

Total PAHs−34
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
100
Sediment Concentration (mg/kg)
Detect
N
Y

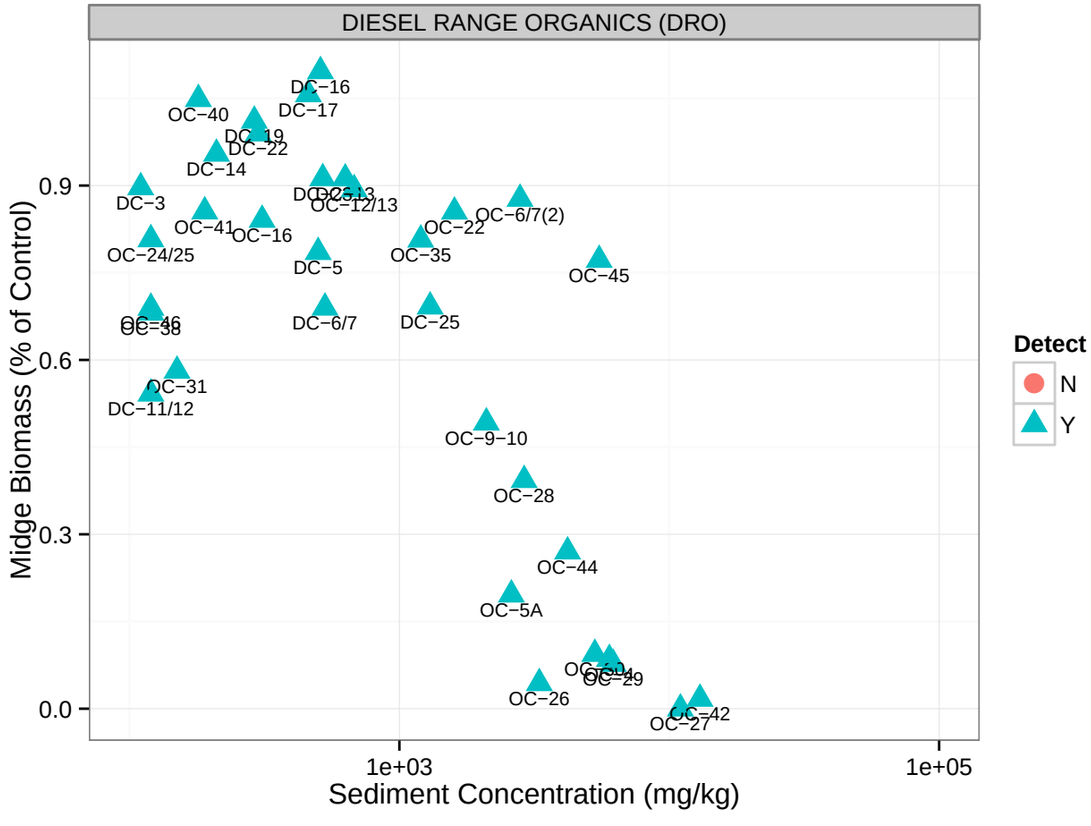

Total PAHs−34, TOC−normalized
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
100
Sediment Concentration (mg/kg at 1%TOC)
Detect
N
Y

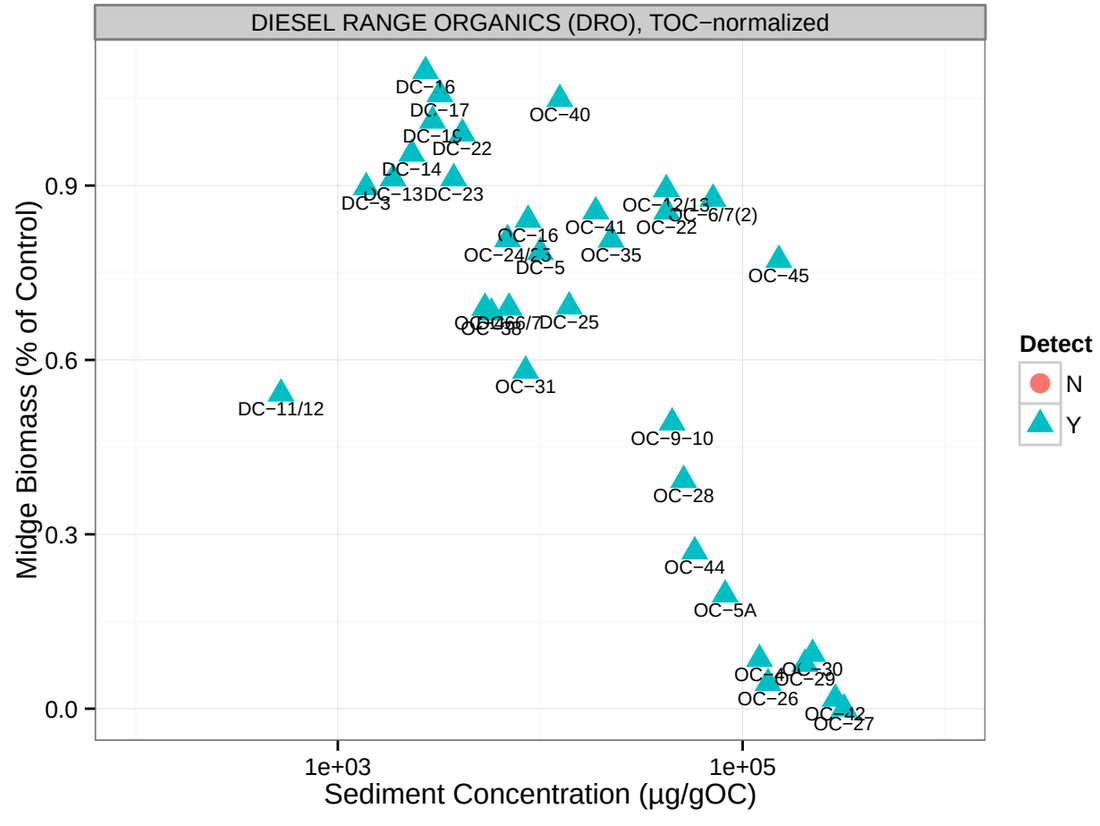

PAH ESBTU
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
10.0
Sediment Concentration (unitless)
Detect
N
Y

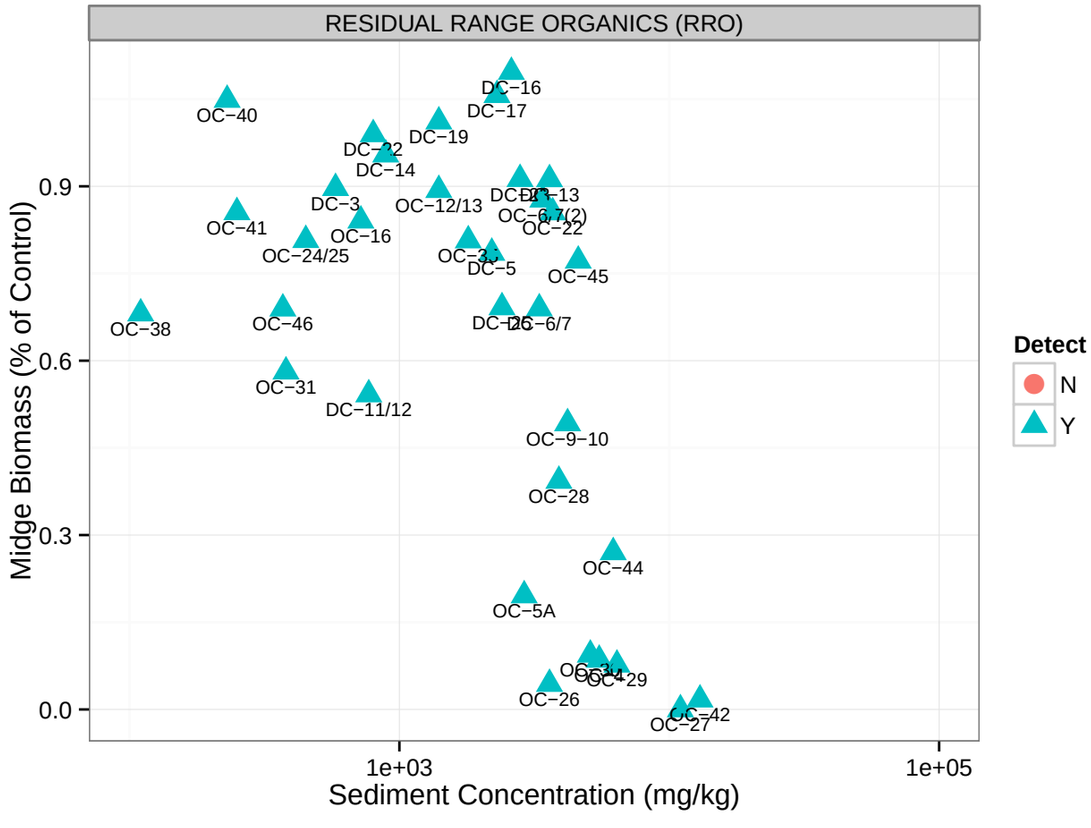

Porewater PAH TU
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
100
Porewater Concentration (unitless)
Detect
N
Y

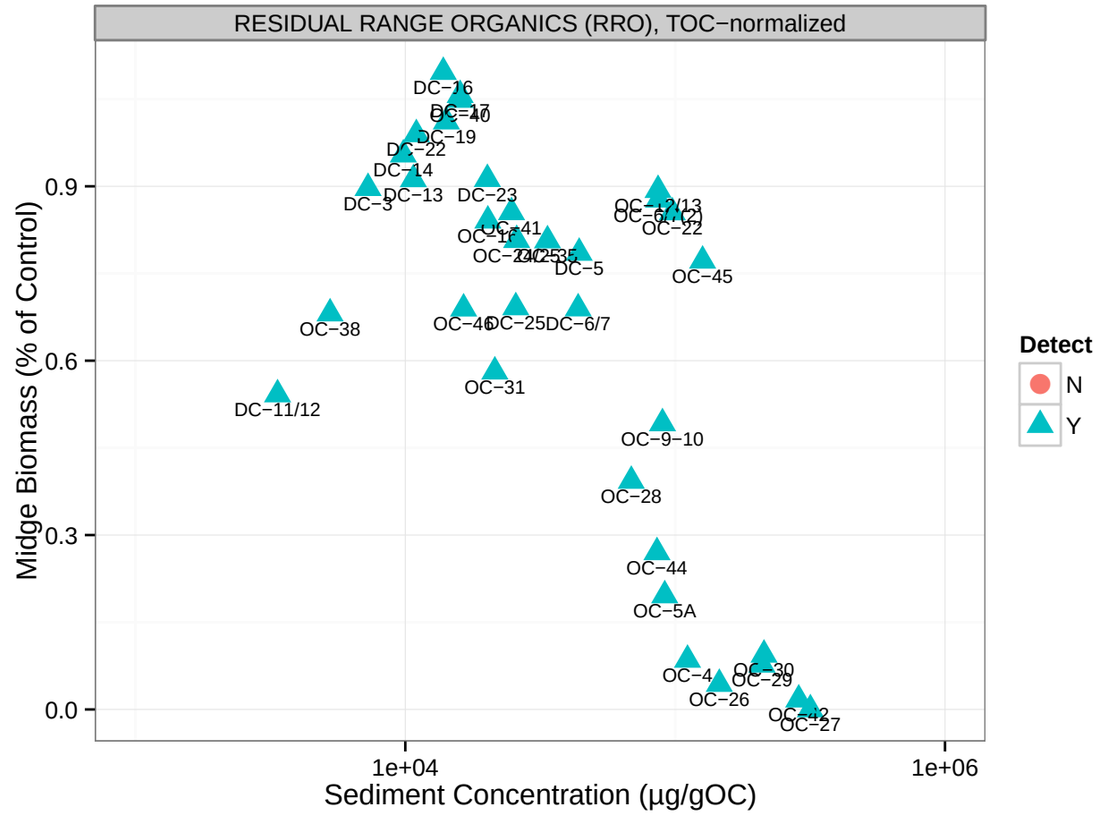

GASOLINE RANGE ORGANICS (GRO)
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
100
Sediment Concentration (mg/kg)
Detect
N
Y

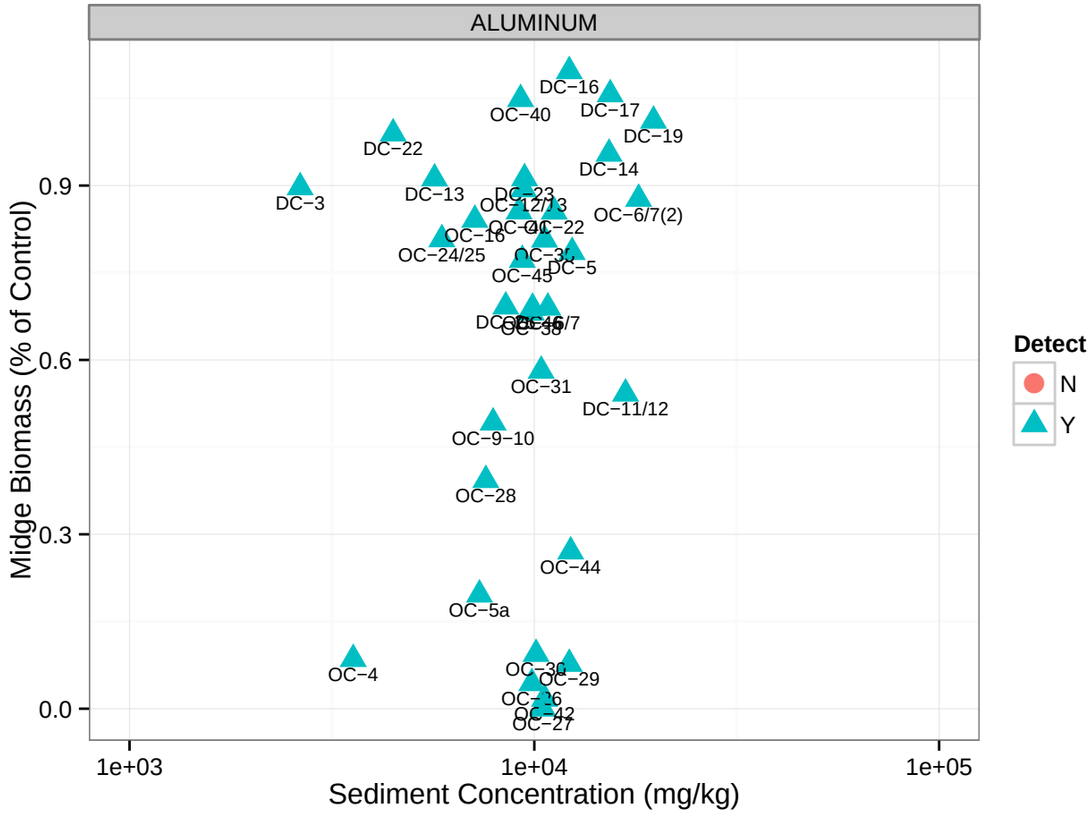

GASOLINE RANGE ORGANICS (GRO), TOC−normalized
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
100
10000
Sediment Concentration (µg/gOC)
Detect
N
Y

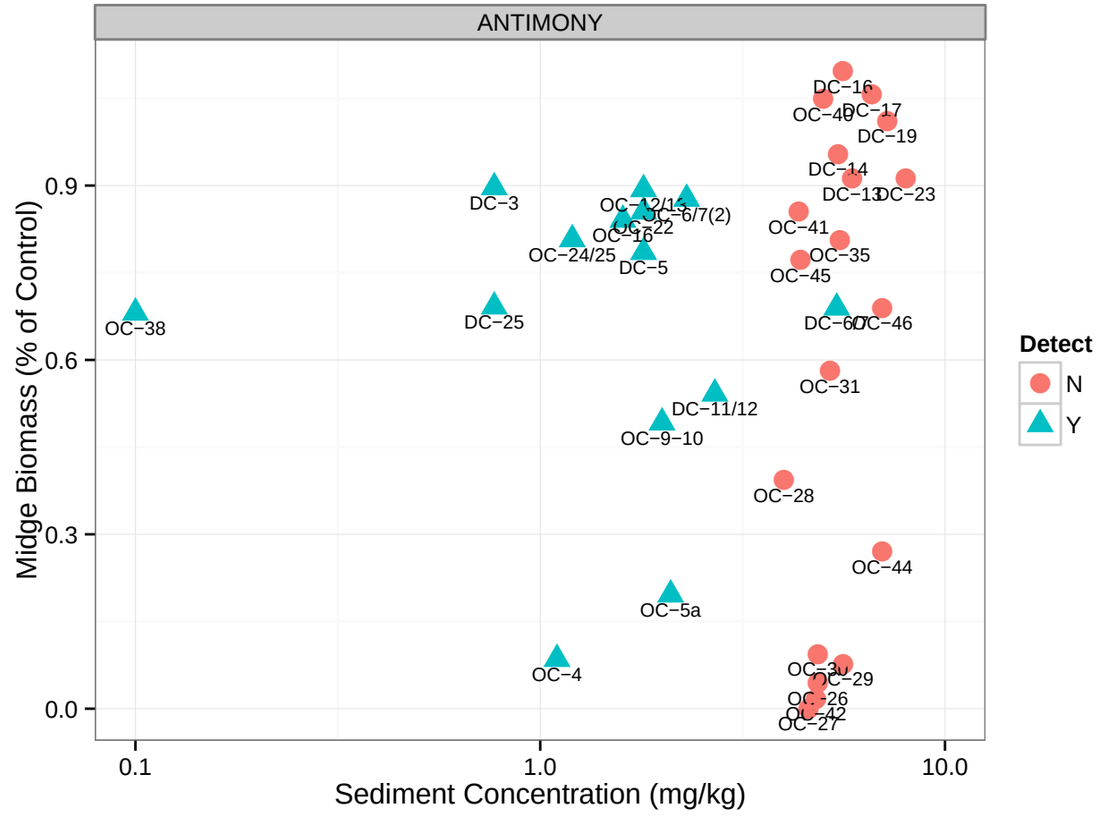

DIESEL RANGE ORGANICS (DRO)
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e+03
1e+05
Sediment Concentration (mg/kg)
Detect
N
Y

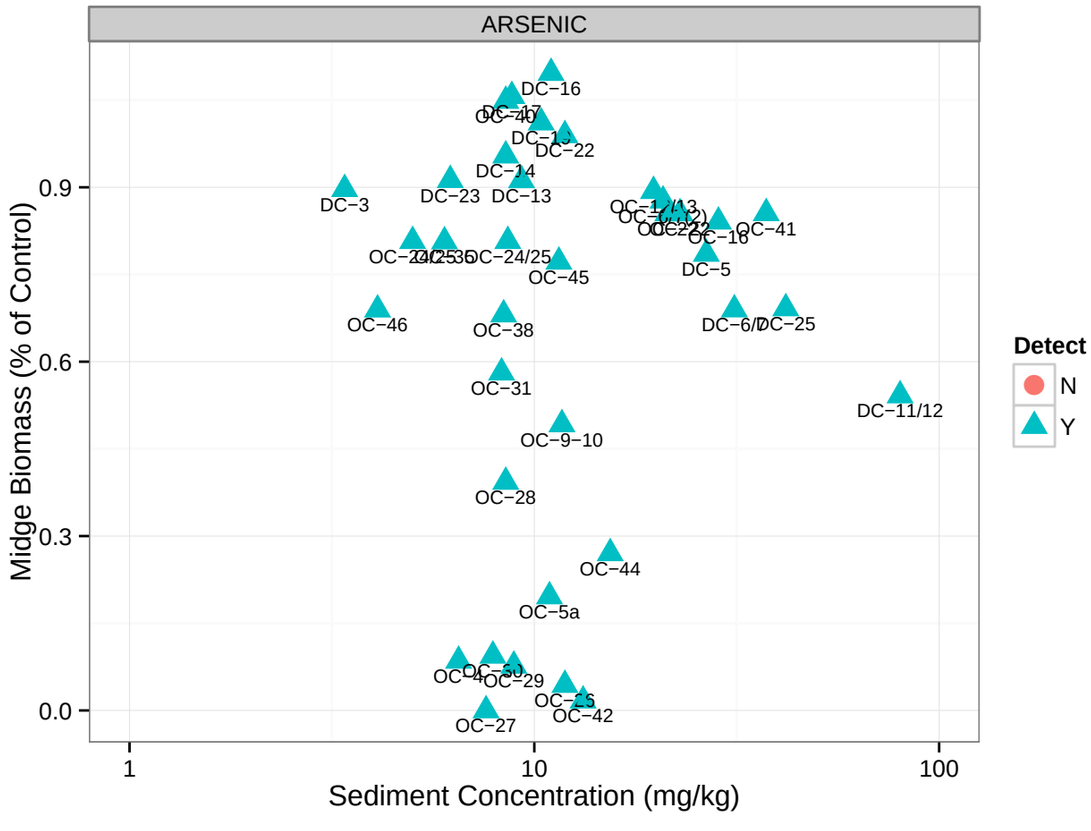

DIESEL RANGE ORGANICS (DRO), TOC−normalized
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e+03
1e+05
Sediment Concentration (µg/gOC)
Detect
N
Y

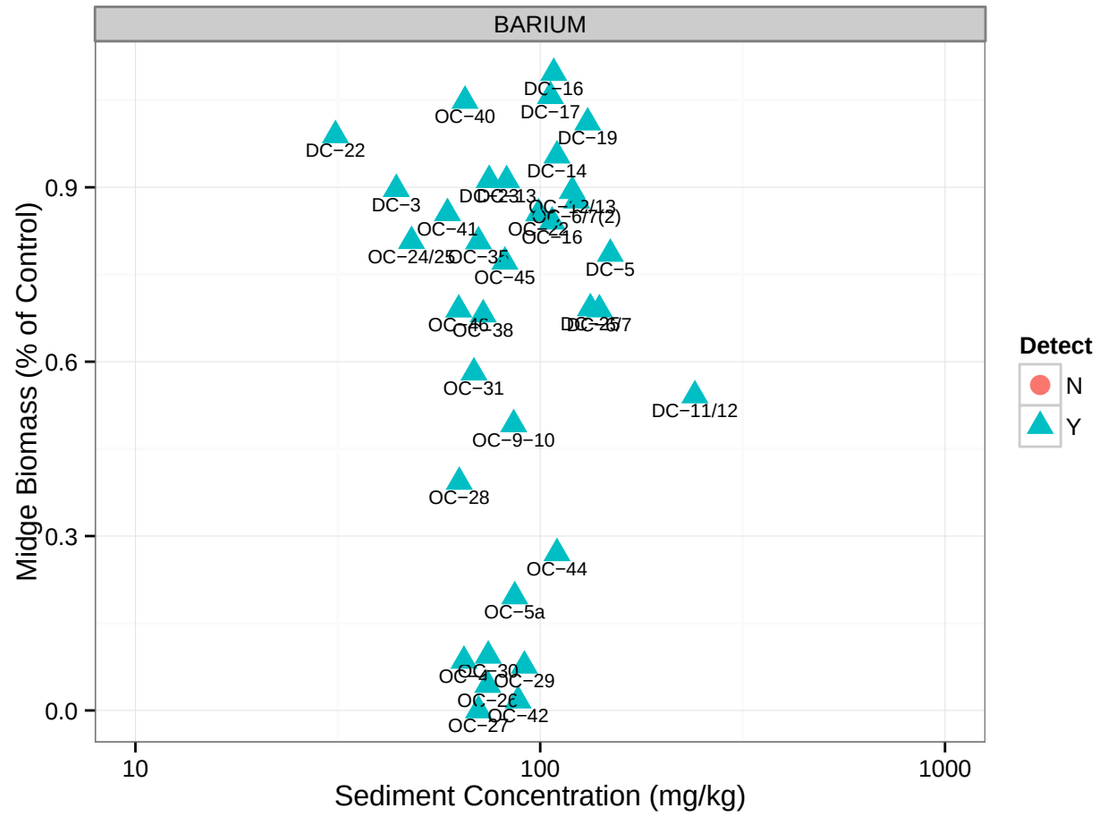

RESIDUAL RANGE ORGANICS (RRO)
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e+03
1e+05
Sediment Concentration (mg/kg)
Detect
N
Y

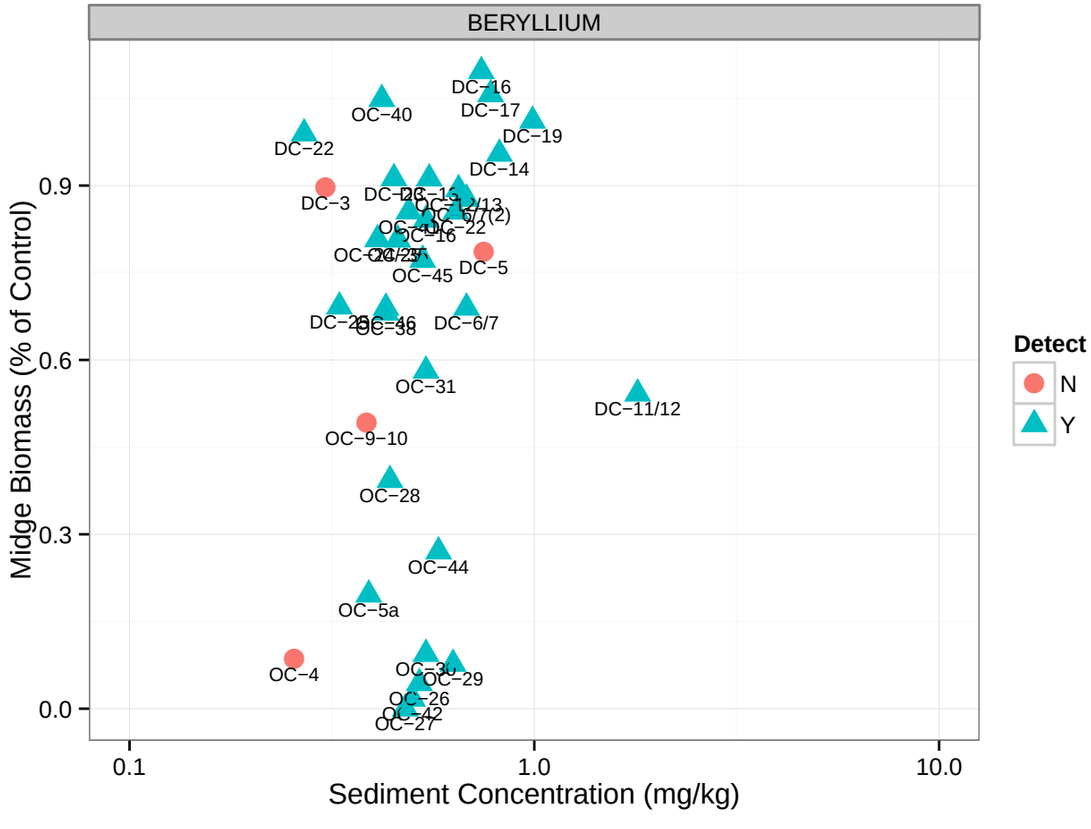

RESIDUAL RANGE ORGANICS (RRO), TOC−normalized
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e+04
1e+06
Sediment Concentration (µg/gOC)
Detect
N
Y

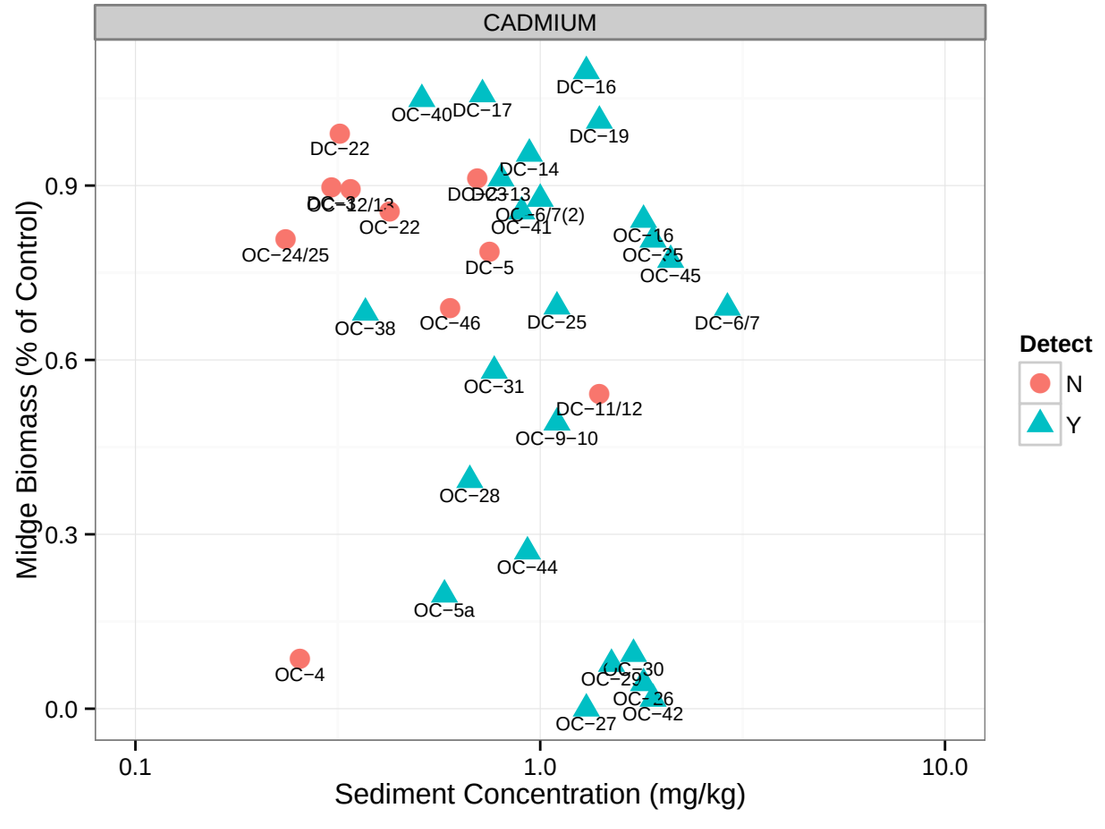

ALUMINUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e+03
1e+04
1e+05
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−16
OC−22
OC−24/25
OC−41
DC−5
OC−45
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−42
OC−27
Detect
N
Y

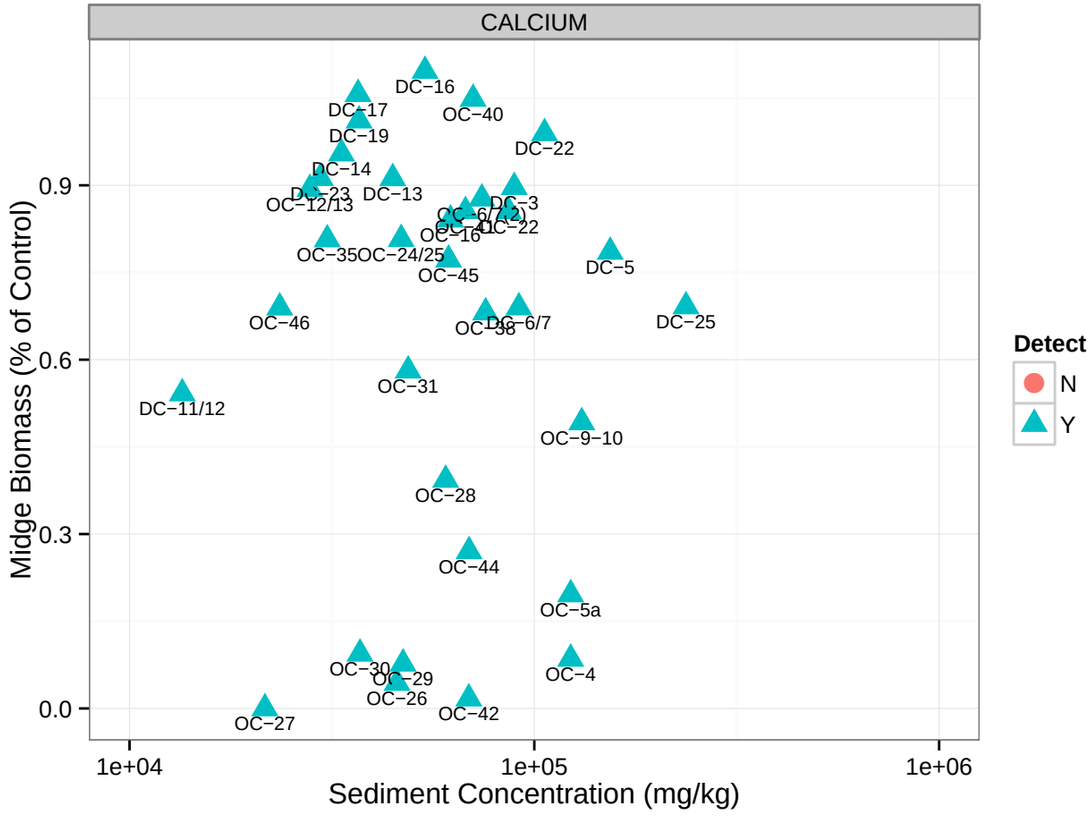

ANTIMONY
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
1.0
10.0
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−14
DC−13
DC−23
DC−3
OC−12/13
OC−6/7(2)
OC−22
OC−41
OC−16
OC−24/25
OC−35
DC−5
OC−45
OC−38
DC−25
DC−46
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

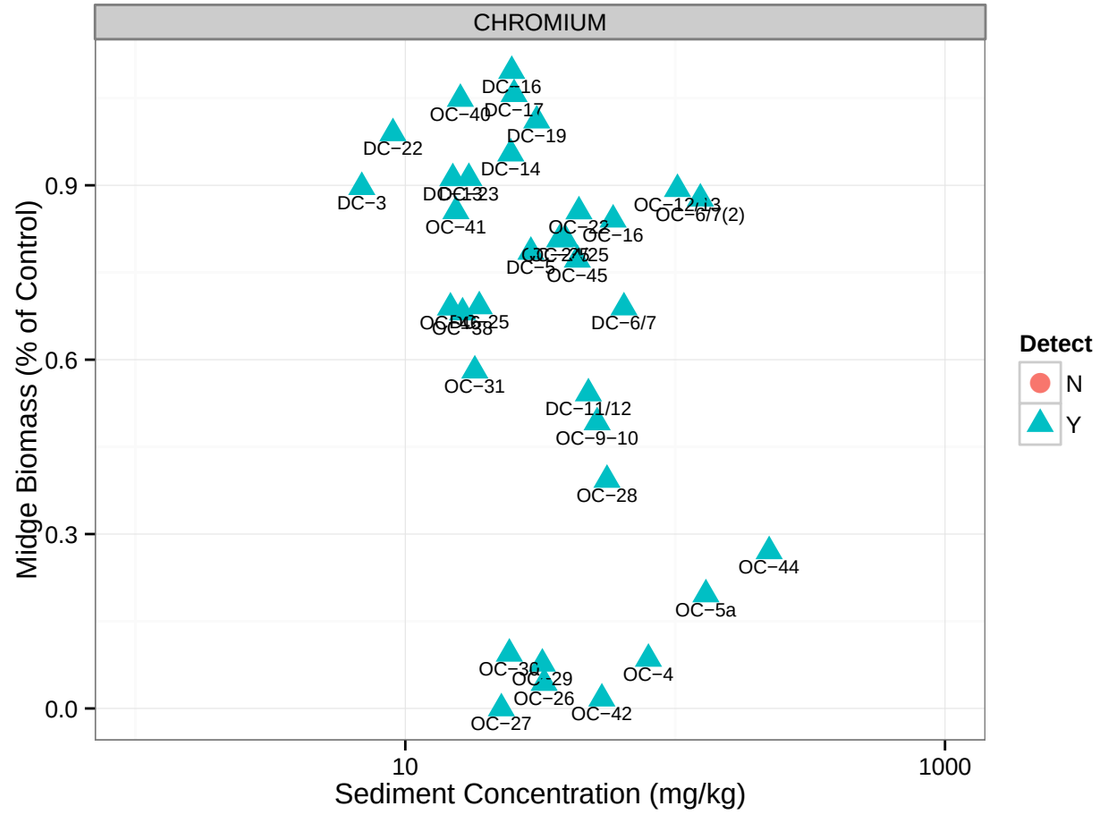

ARSENIC
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
10
100
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−23
DC−13
OC−41
OC−16
DC−5
OC−24/25
OC−45
OC−46
OC−38
DC−6/7
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−29
OC−42
OC−27
Detect
N
Y


BARIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
100
1000
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−41
OC−22
OC−16
OC−24/25
OC−35
DC−5
OC−45
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

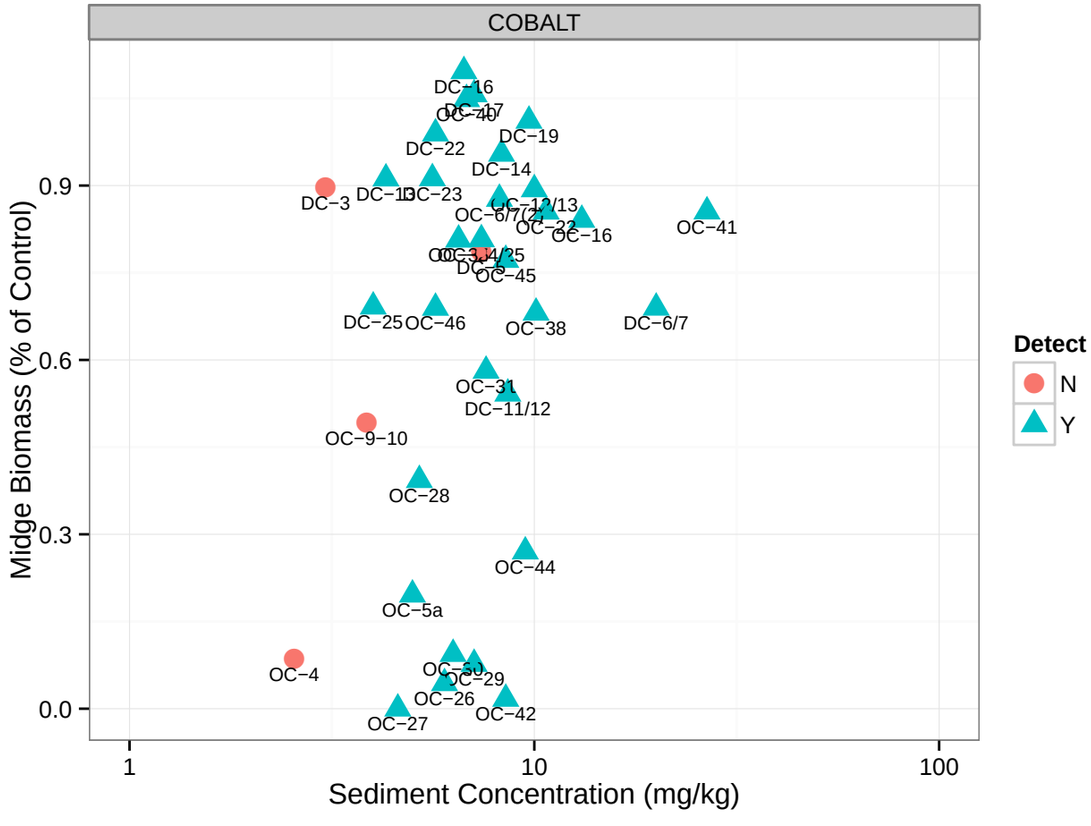

BERYLLIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
1.0
10.0
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−41
OC−22
OC−16
OC−24/25
DC−5
OC−45
DC−25
OC−46
OC−38
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

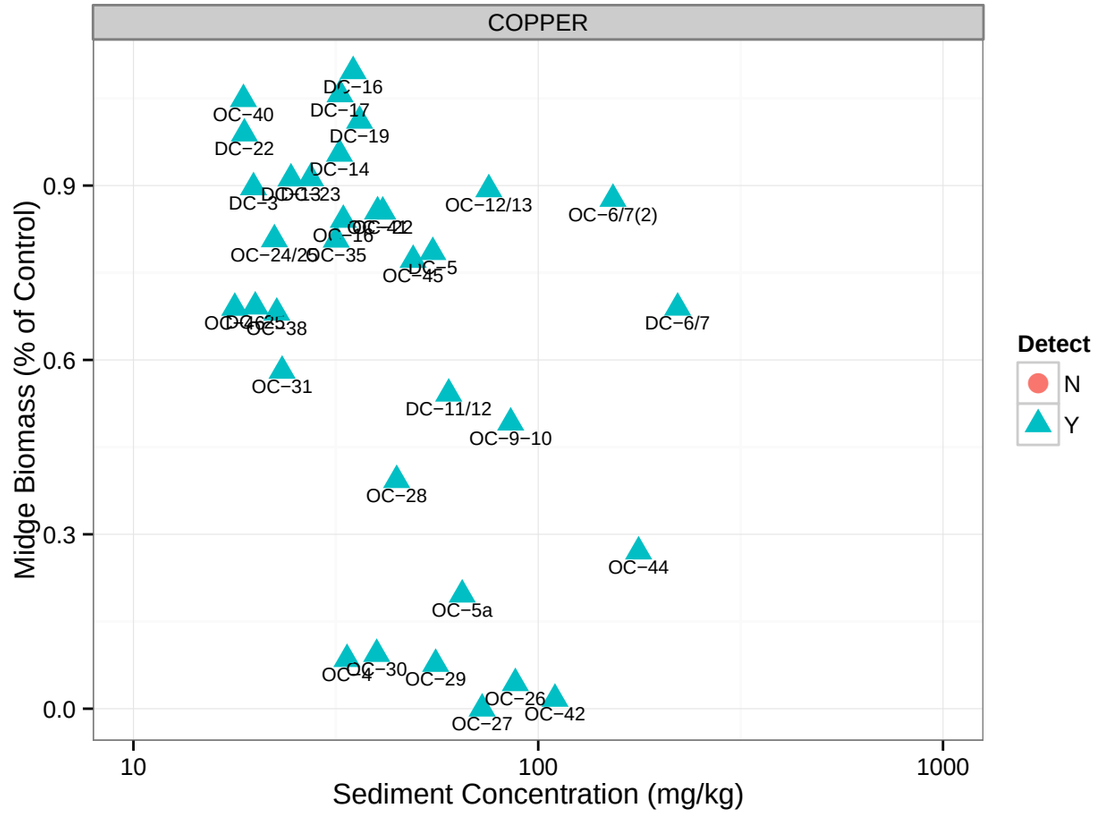

CADMIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
1.0
10.0
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−41
OC−22
OC−16
OC−24/25
DC−5
OC−45
OC−38
OC−46
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

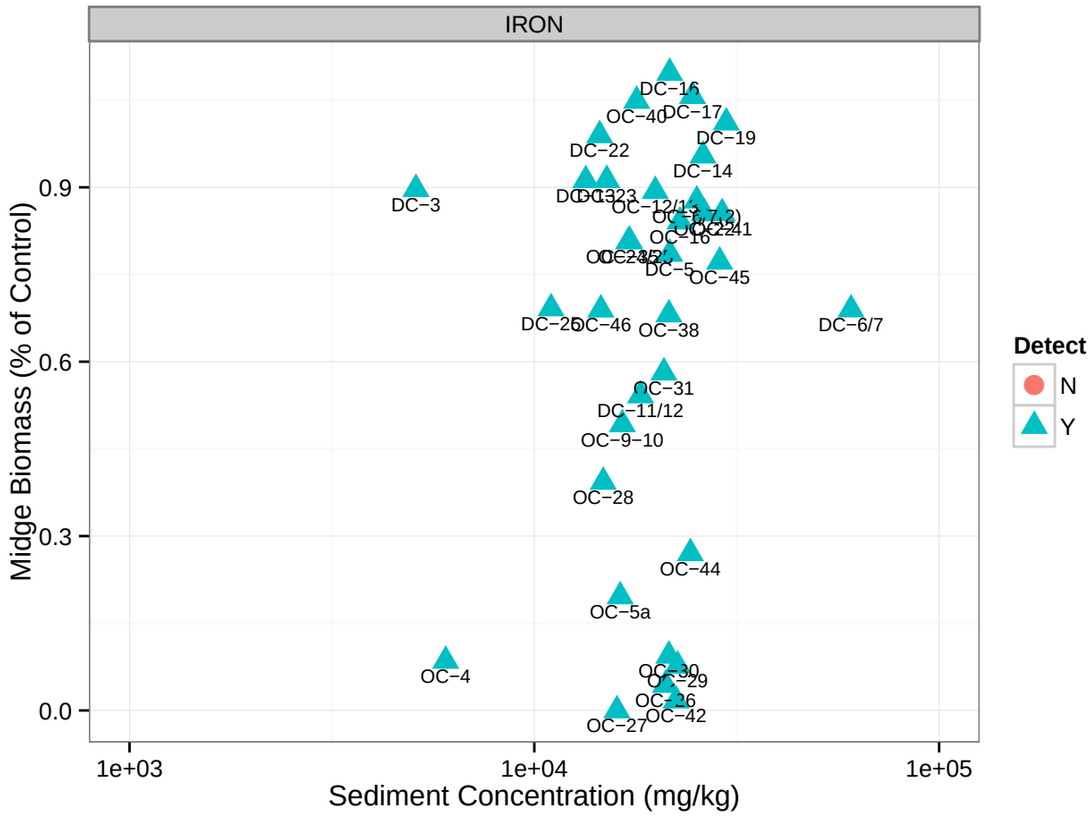

CALCIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e+04
1e+05
1e+06
Sediment Concentration (mg/kg)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−23
DC−13
OC−12/13
DC−3
OC−6/7(2)
OC−41
OC−22
OC−16
OC−35
OC−24/25
OC−45
DC−5
OC−46
OC−38
DC−6/7
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

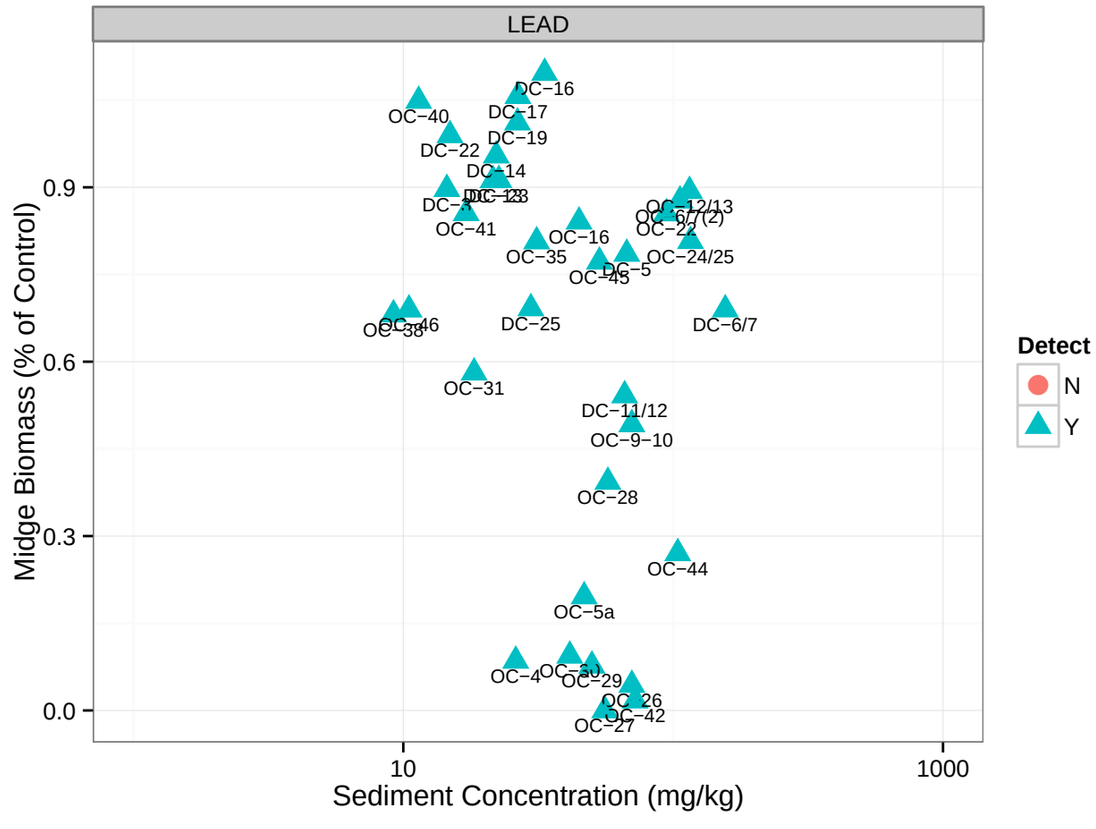

CHROMIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
1000
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−41
OC−22
OC−16
DC−5
OC−45
OC−38
OC−46
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

Attachment 2a: Analytical Parameters versus Midge Biomass, Duck and Otter Creeks

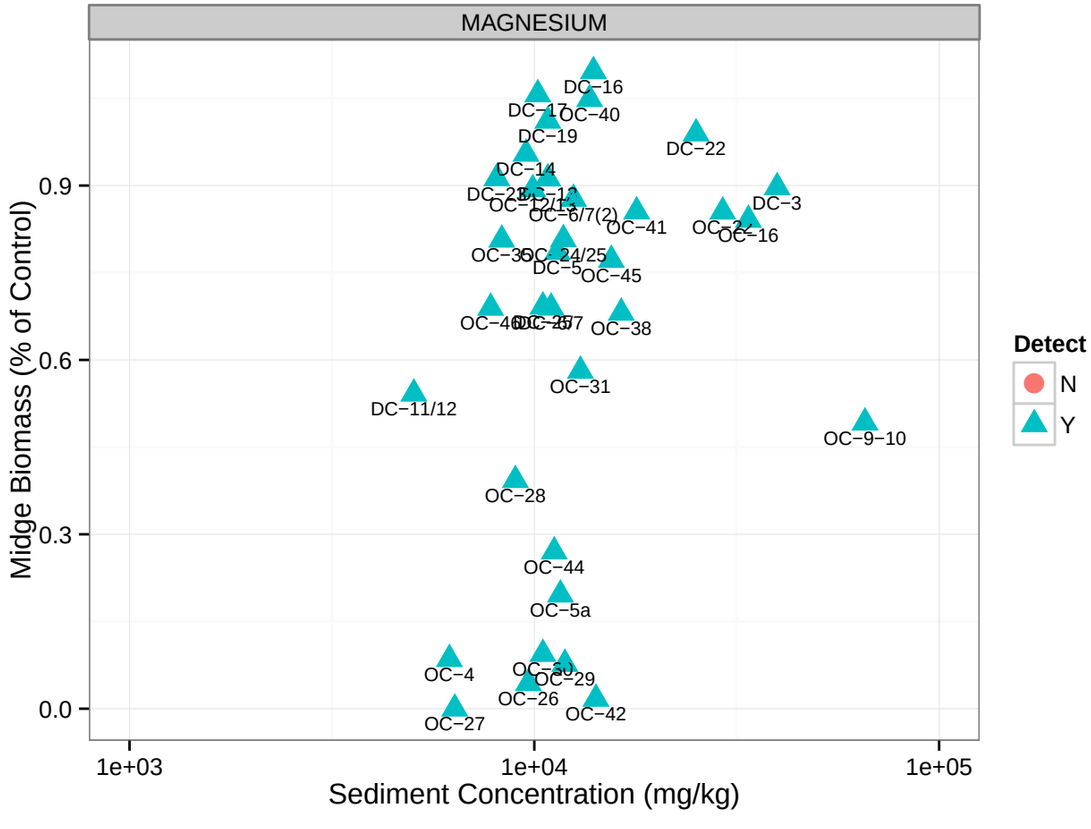


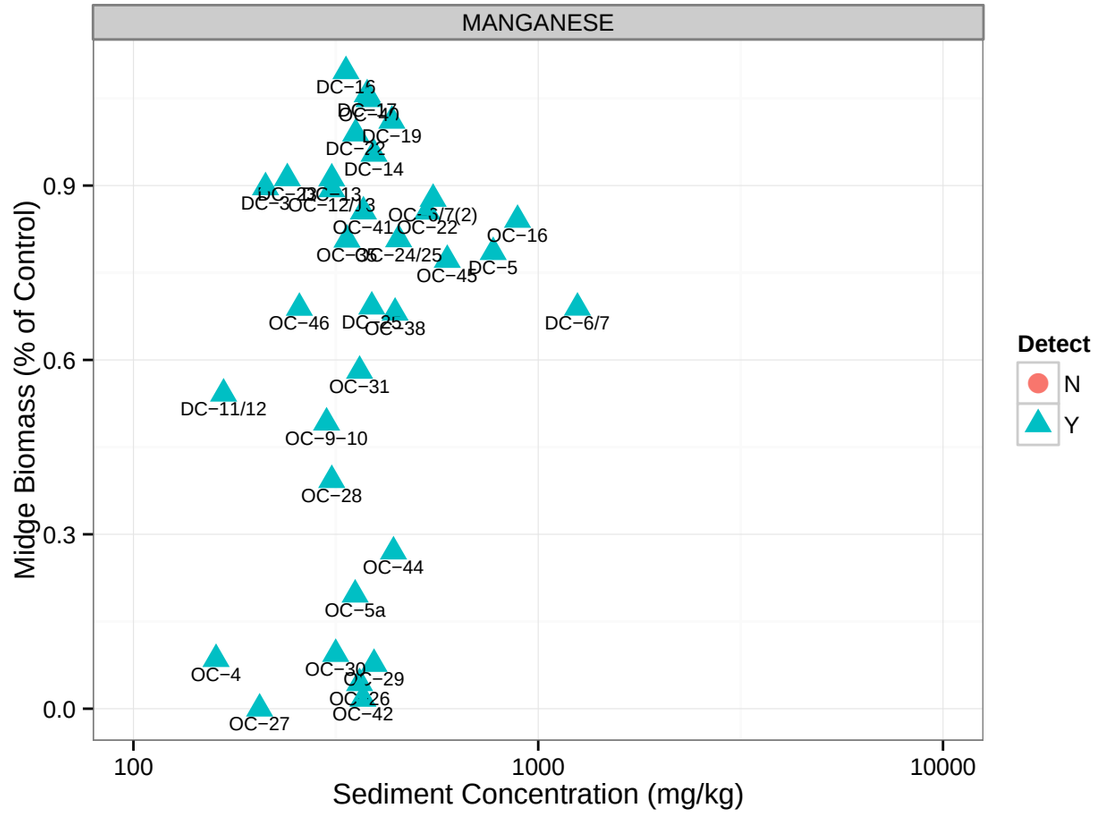


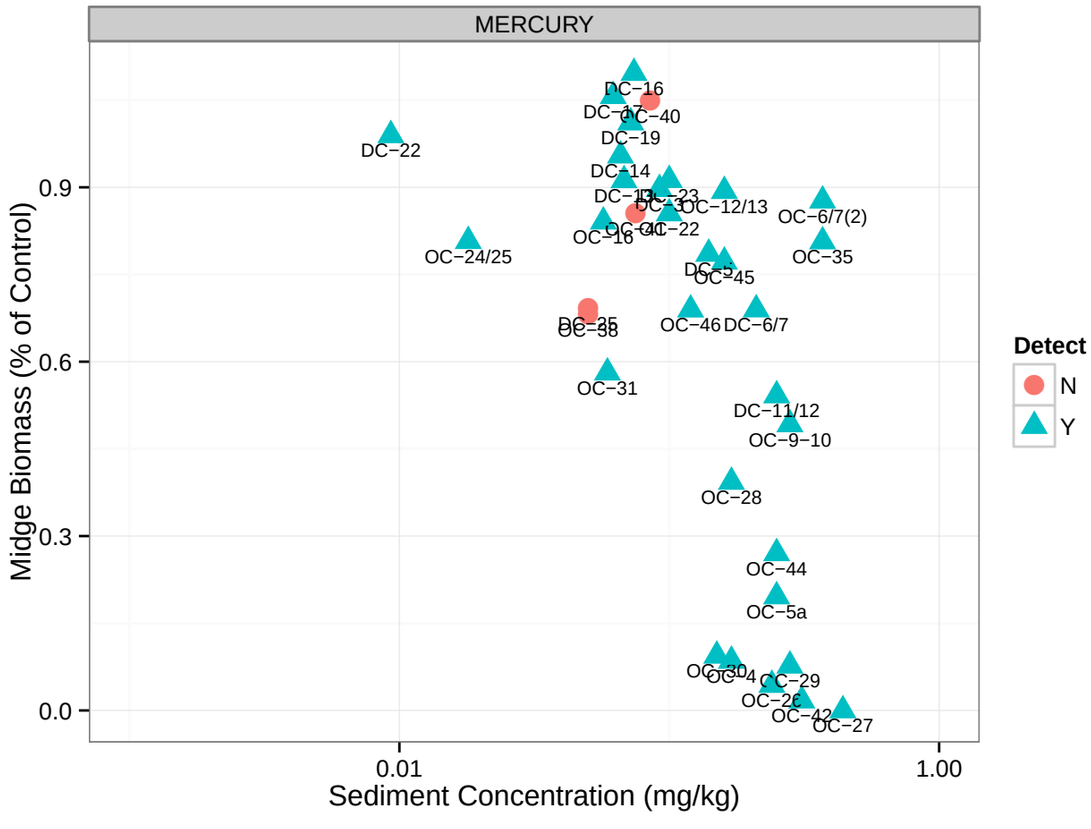


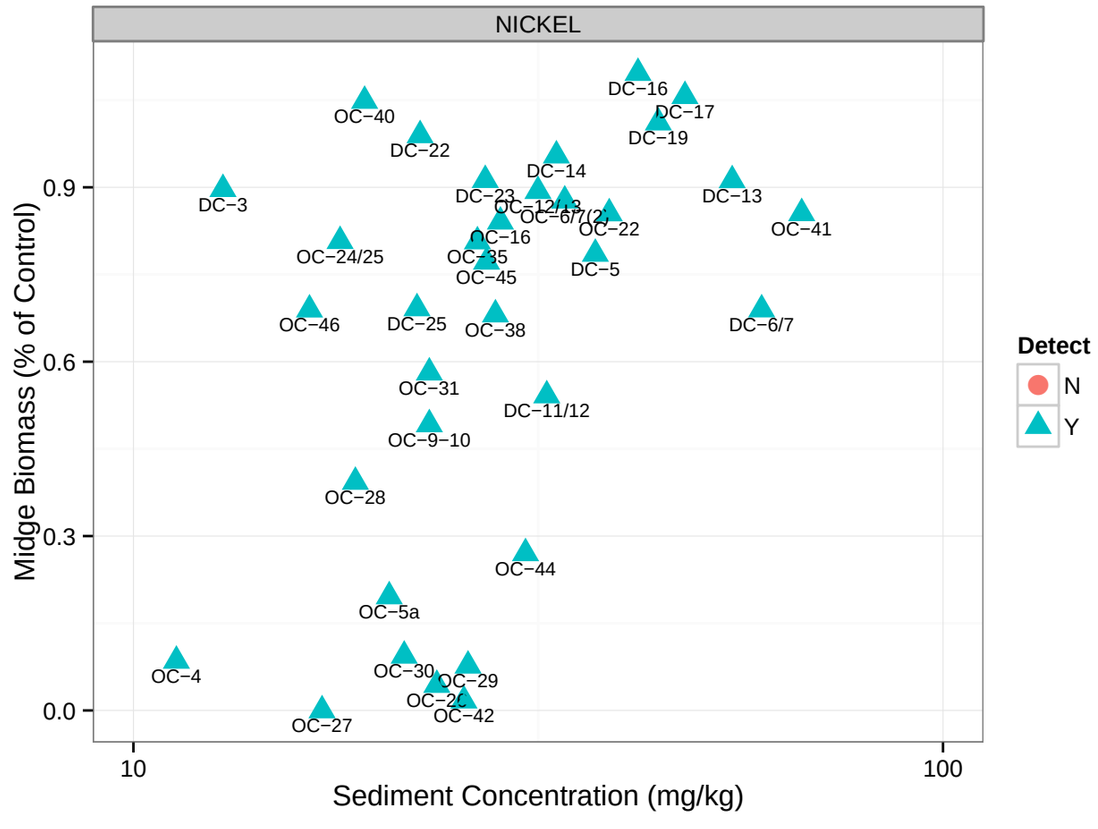


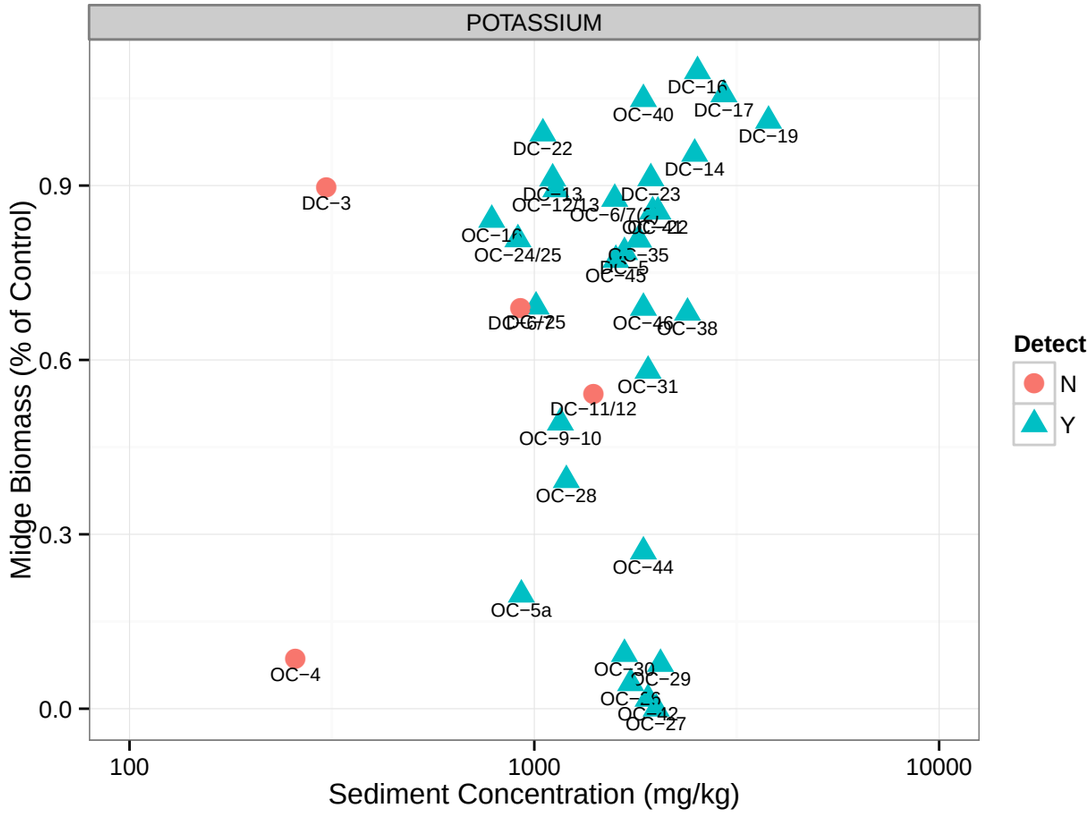
Attachment 2a: Analytical Parameters versus Midge Biomass, Duck and Otter Creeks

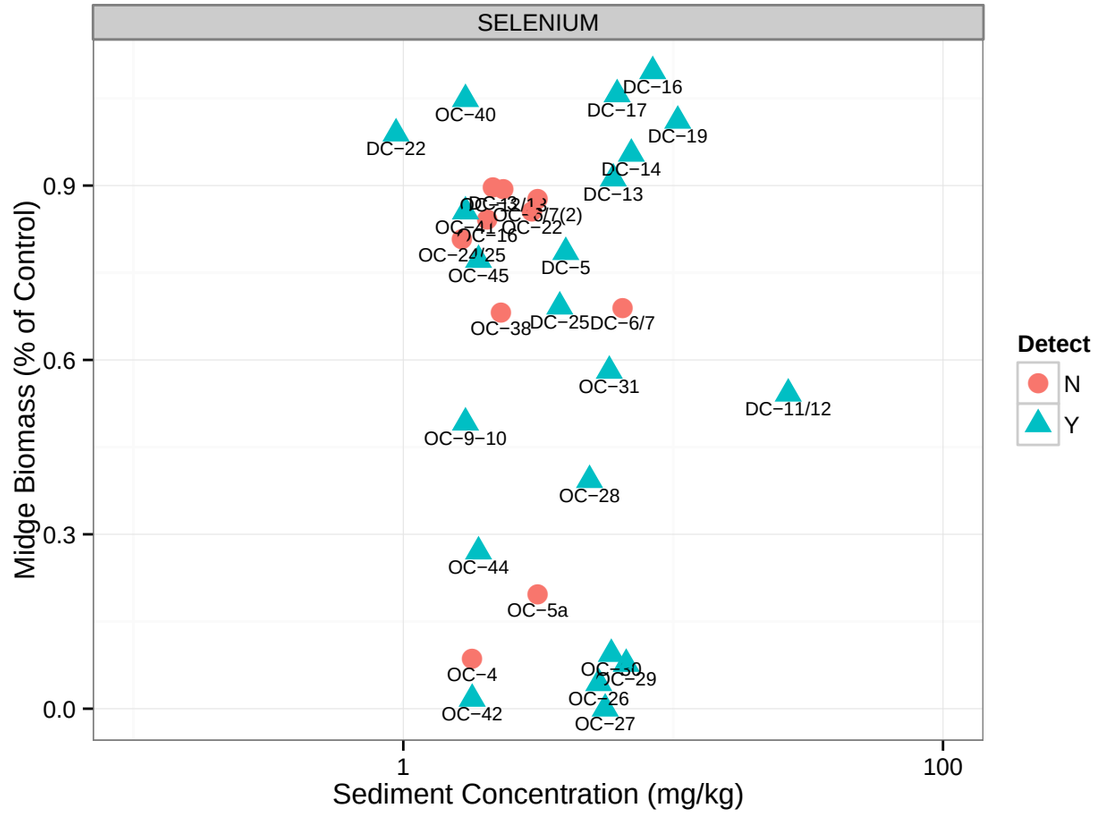


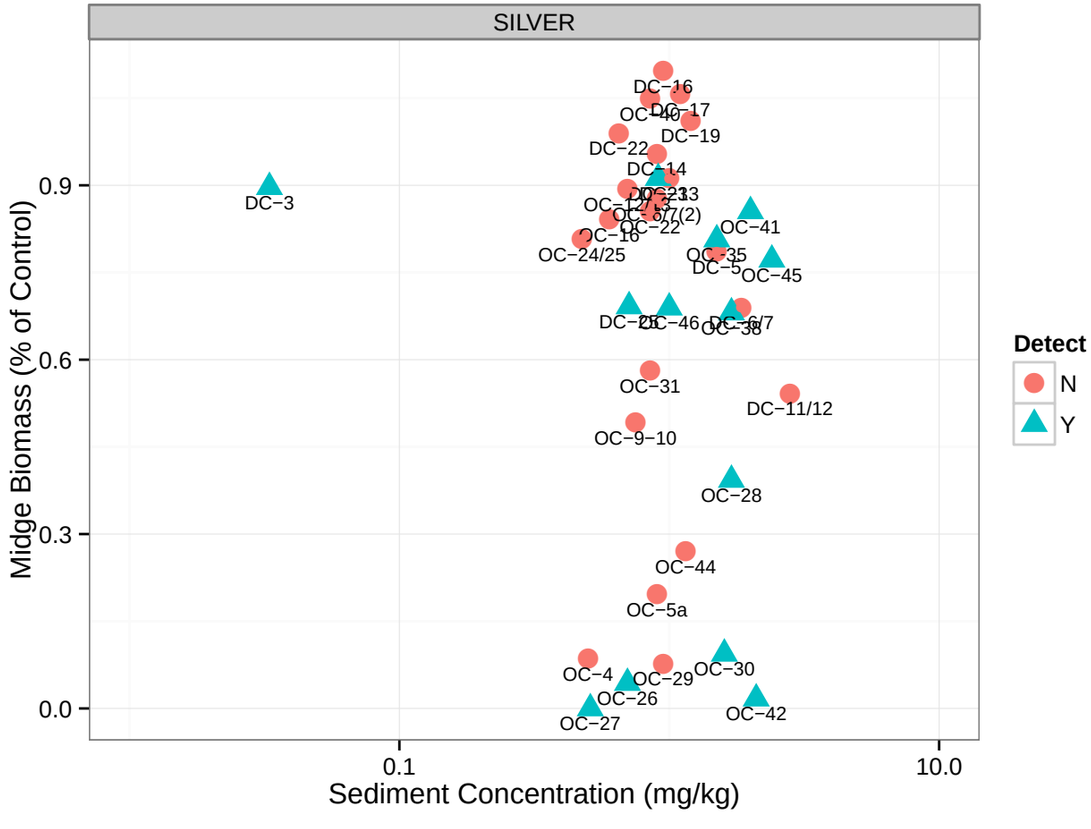


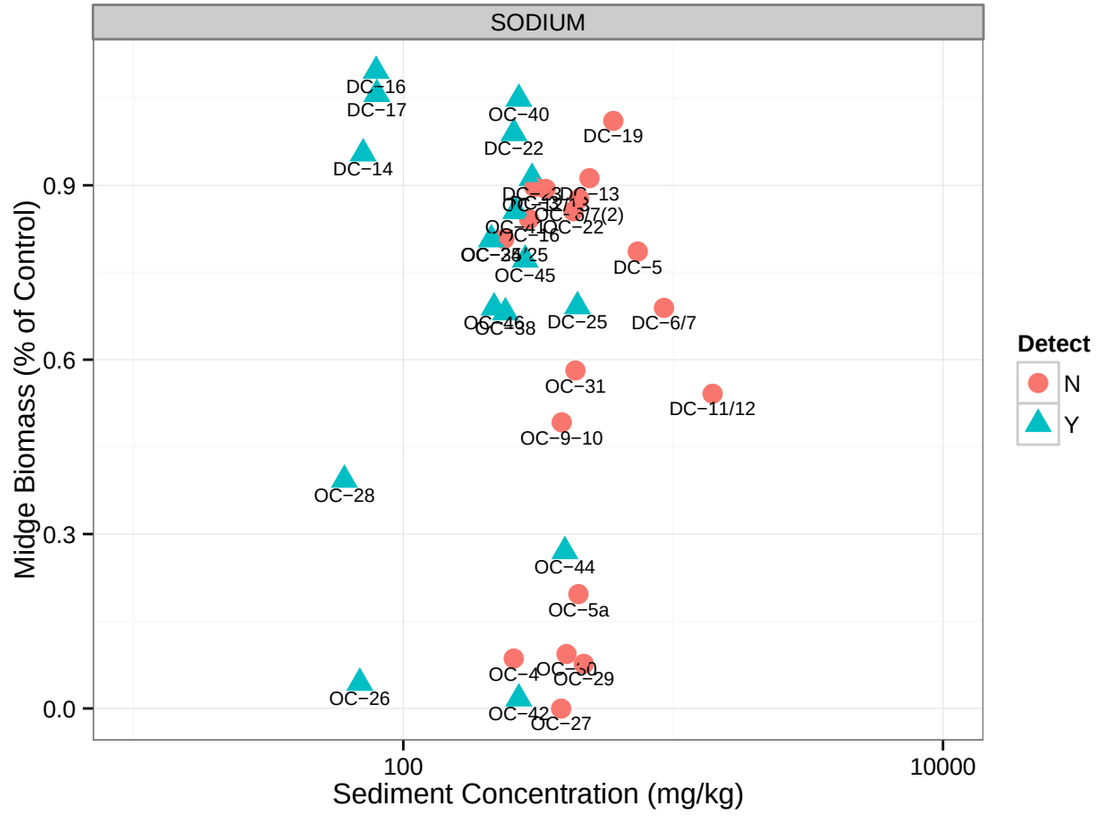




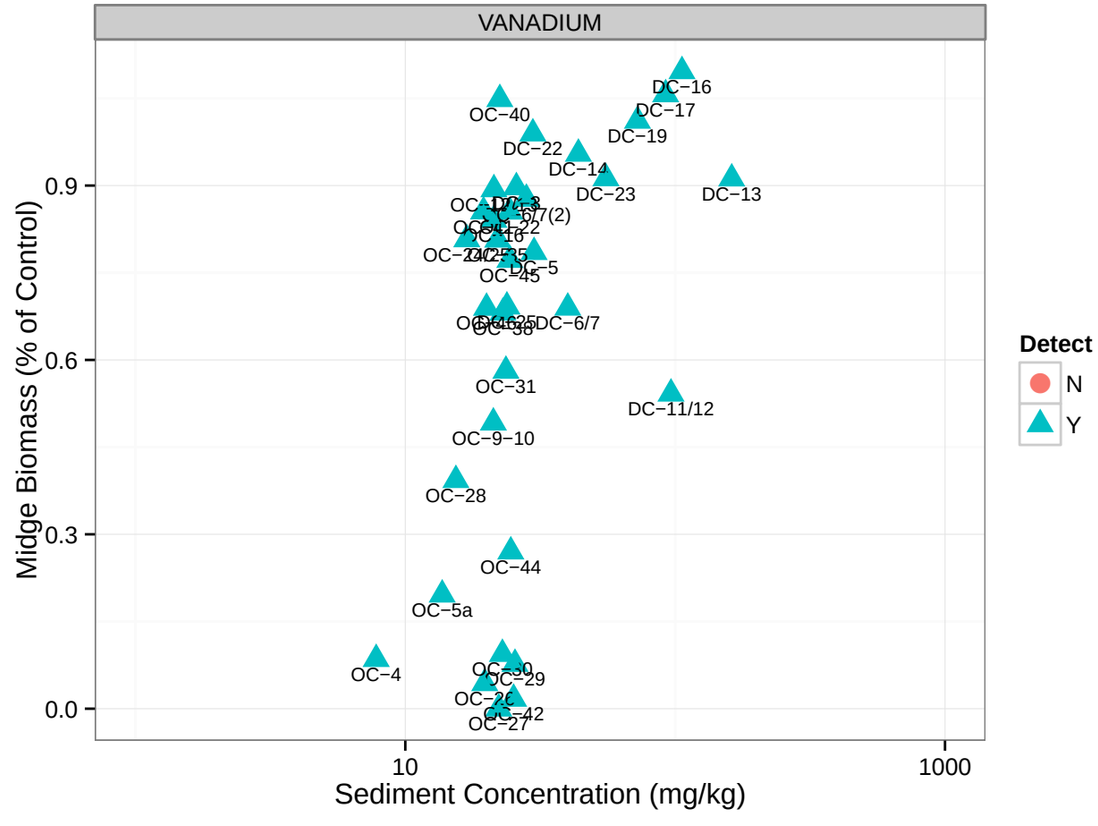

POTASSIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
100
1000
10000
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−24/25
OC−35
DC−5
OC−45
DC−6/7
OC−46
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

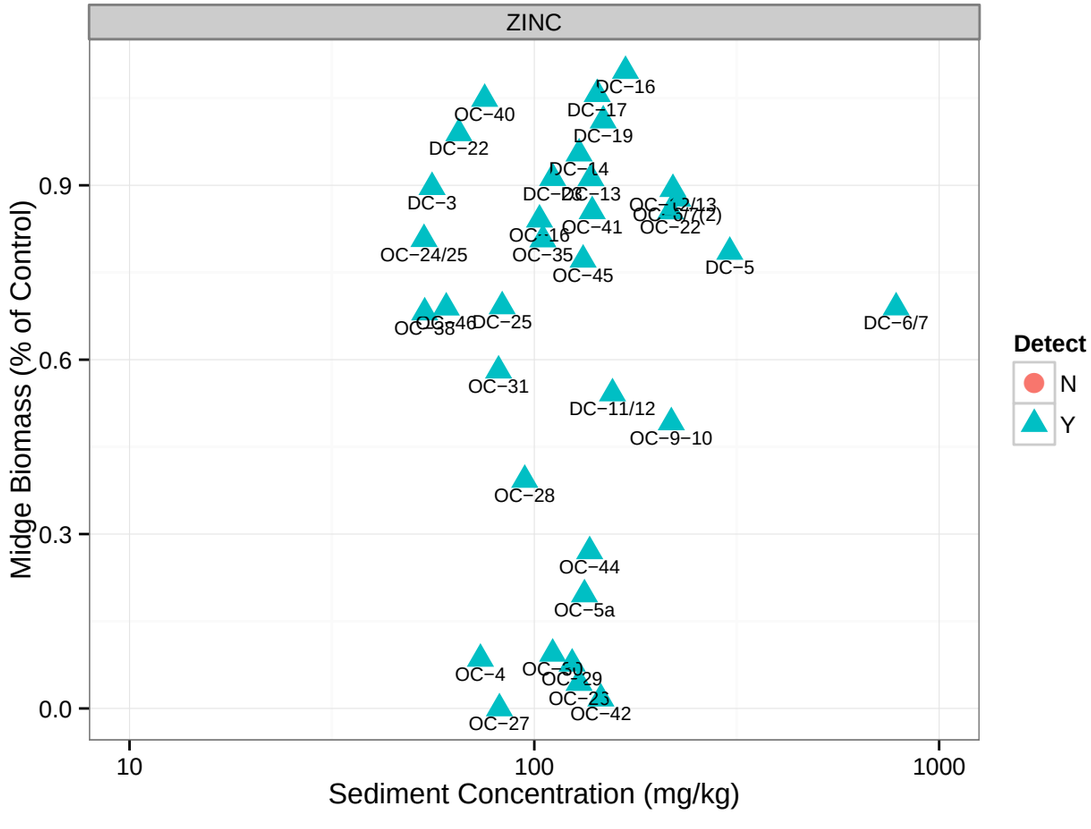

SELENIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
100
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−13
OC−6/7(2)
OC−22
OC−24/25
DC−5
OC−45
OC−38
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

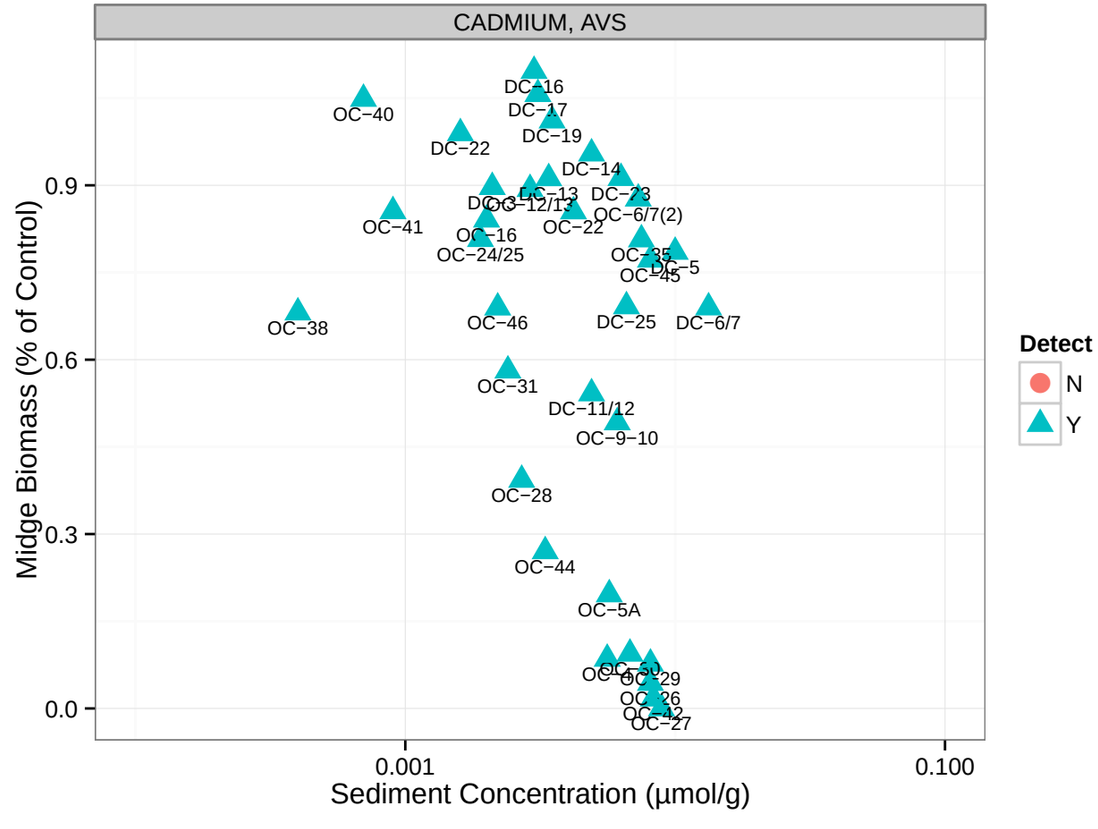

SILVER
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
10.0
Sediment Concentration (mg/kg)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−3
OC−12/13
OC−6/7(2)
OC−22
OC−41
OC−16
OC−24/25
OC−35
DC−5
OC−45
DC−25
OC−46
DC−6/7
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−30
OC−26
OC−42
OC−27
Detect
N
Y

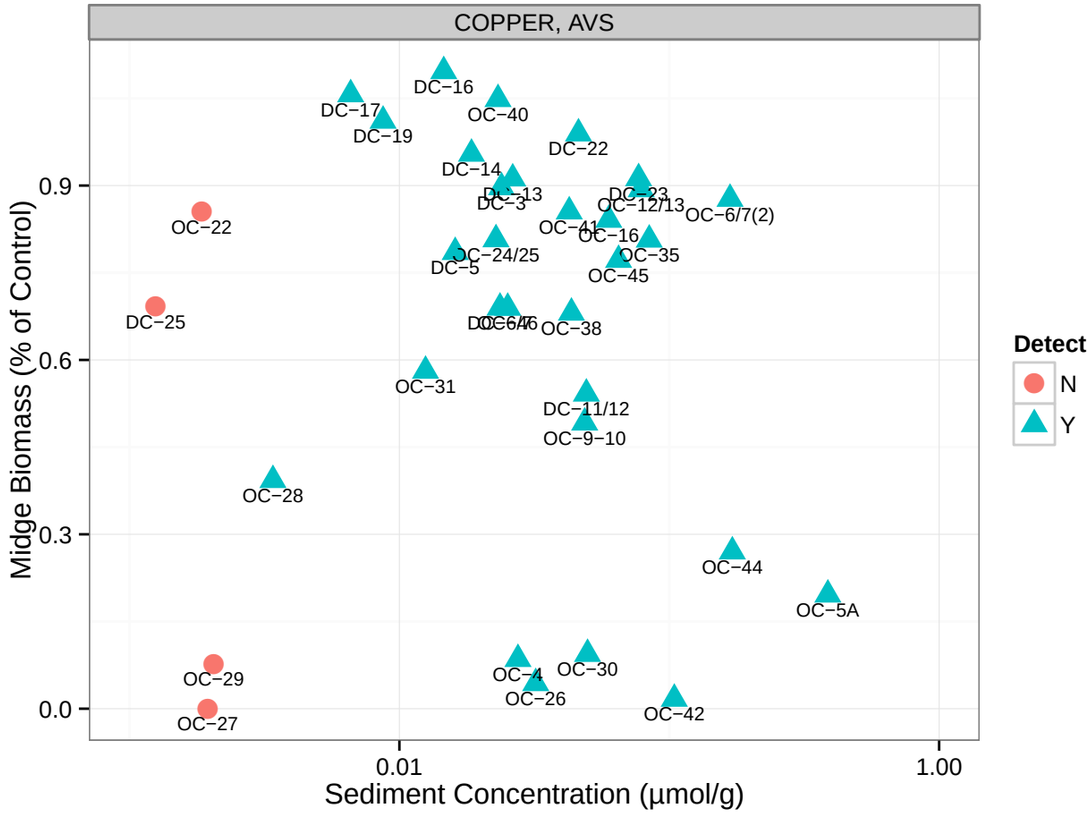

SODIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
100
10000
Sediment Concentration (mg/kg)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−13
OC−6/7(2)
OC−22
OC−16
OC−45
DC−5
OC−46
OC−38
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

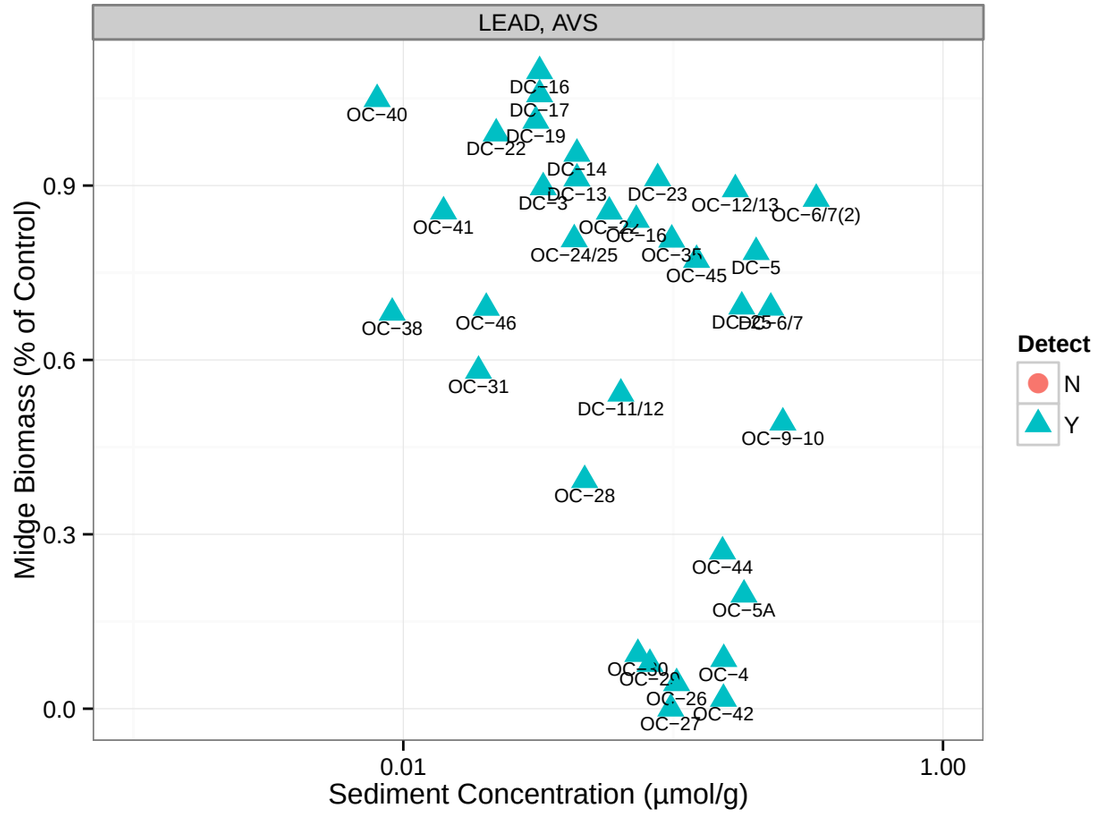

THALLIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
10
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−14
DC−13
DC−3
DC−12/13
OC−6,7(2)
OC−16
OC−41
OC−22
OC−24/25
OC−45
DC−5
OC−38
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

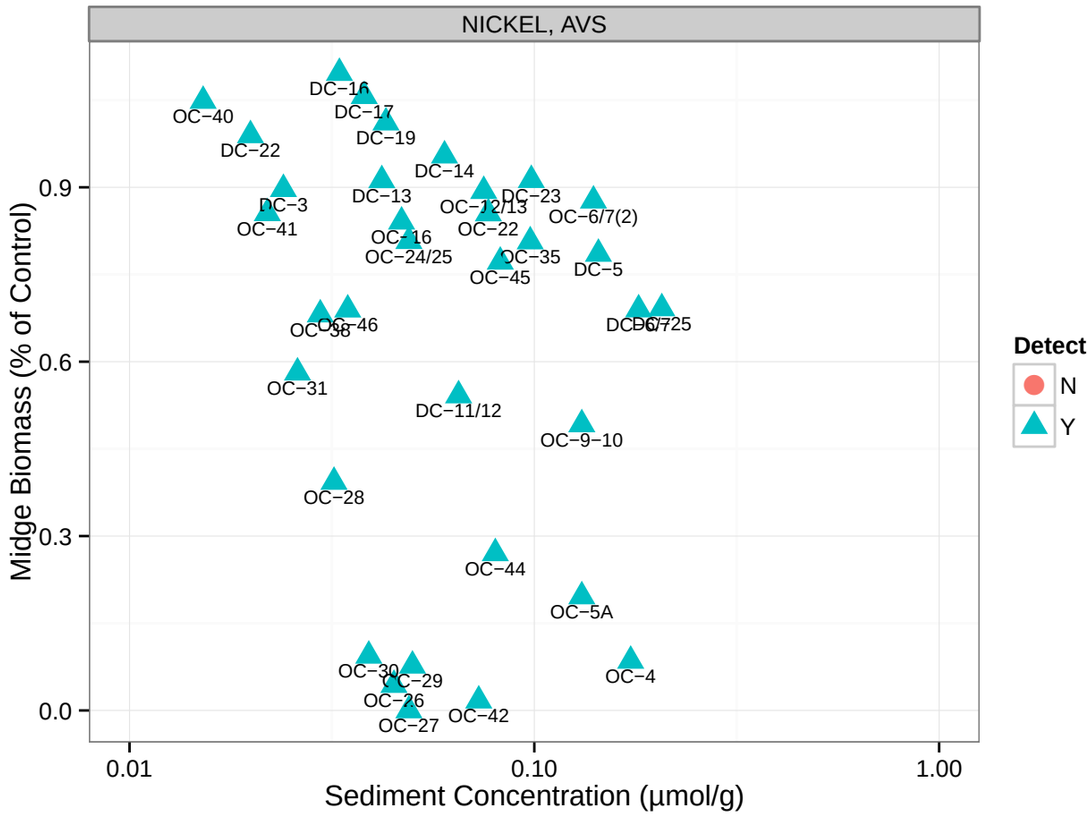

VANADIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
1000
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−23
DC−13
OC−6/7(2)
OC−22
OC−45
DC−5
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−42
OC−27
Detect
N
Y

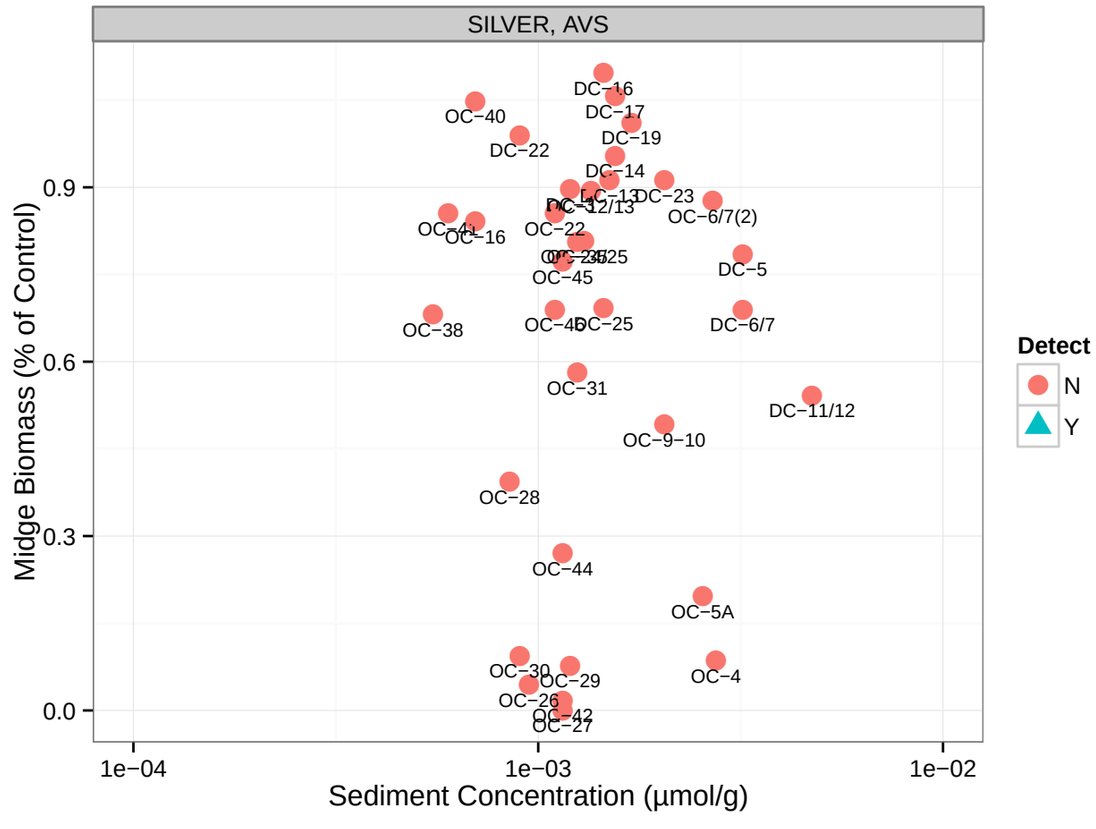

ZINC
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
100
1000
Sediment Concentration (mg/kg)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−13
DC−12/13
OC−6/7(2)
OC−16
OC−41
OC−22
OC−24/25
OC−35
OC−45
DC−5
OC−38
OC−46
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−23
OC−42
OC−27
Detect
N
Y

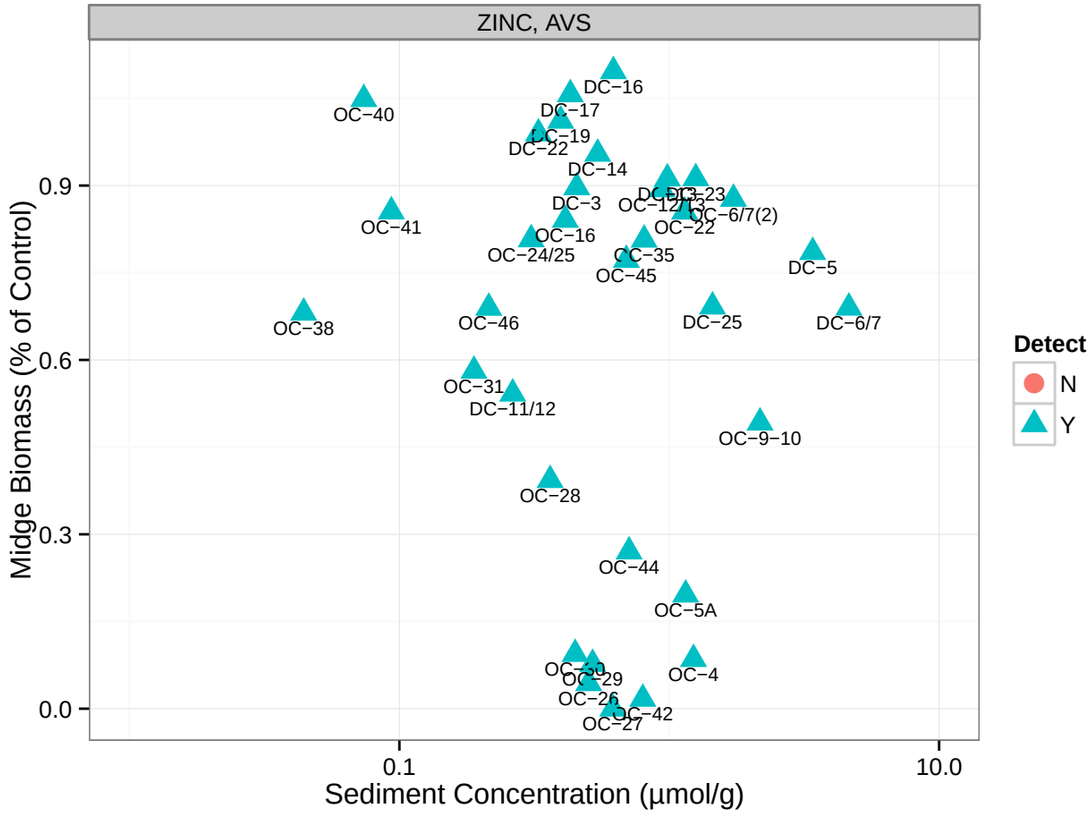

CADMIUM, AVS
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.001
0.100
Sediment Concentration (µmol/g)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−23
DC−13
DC−12/13
OC−6/7(2)
OC−41
OC−16
OC−22
OC−24/25
OC−35
DC−5
OC−45
OC−38
OC−46
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

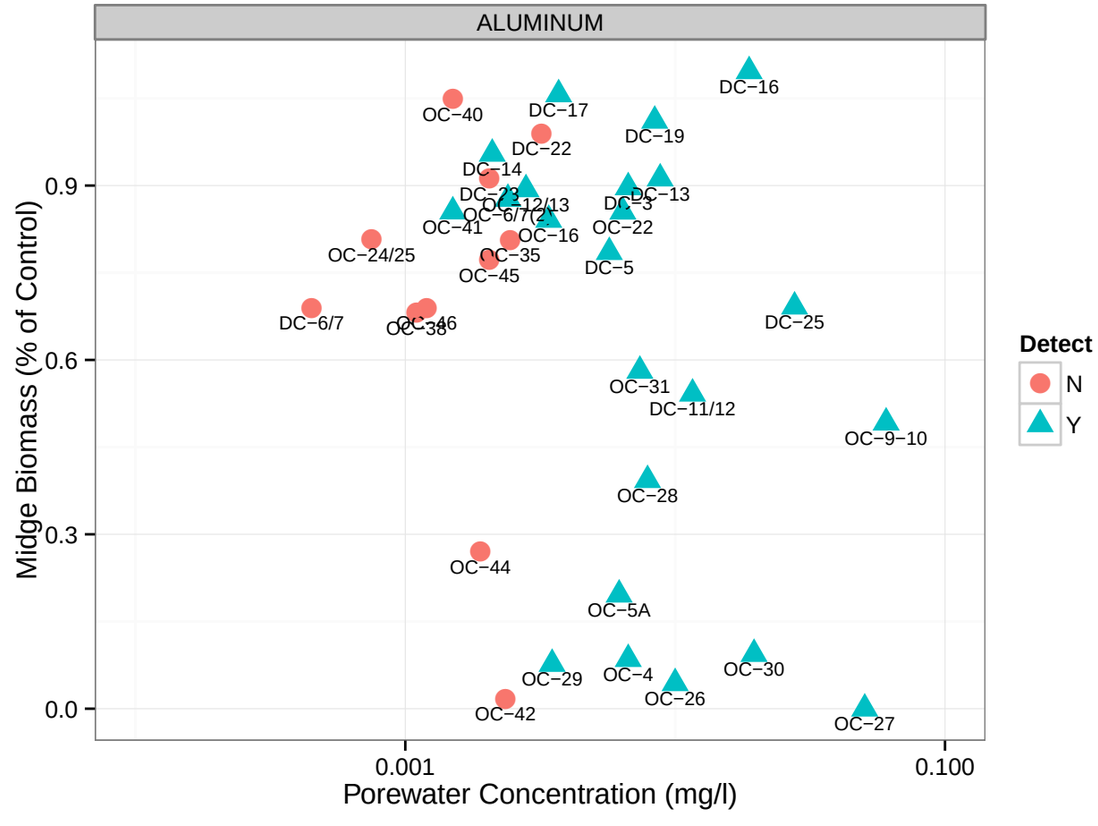

COPPER, AVS
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.01
1.00
Sediment Concentration (µmol/g)
Detect
N
Y

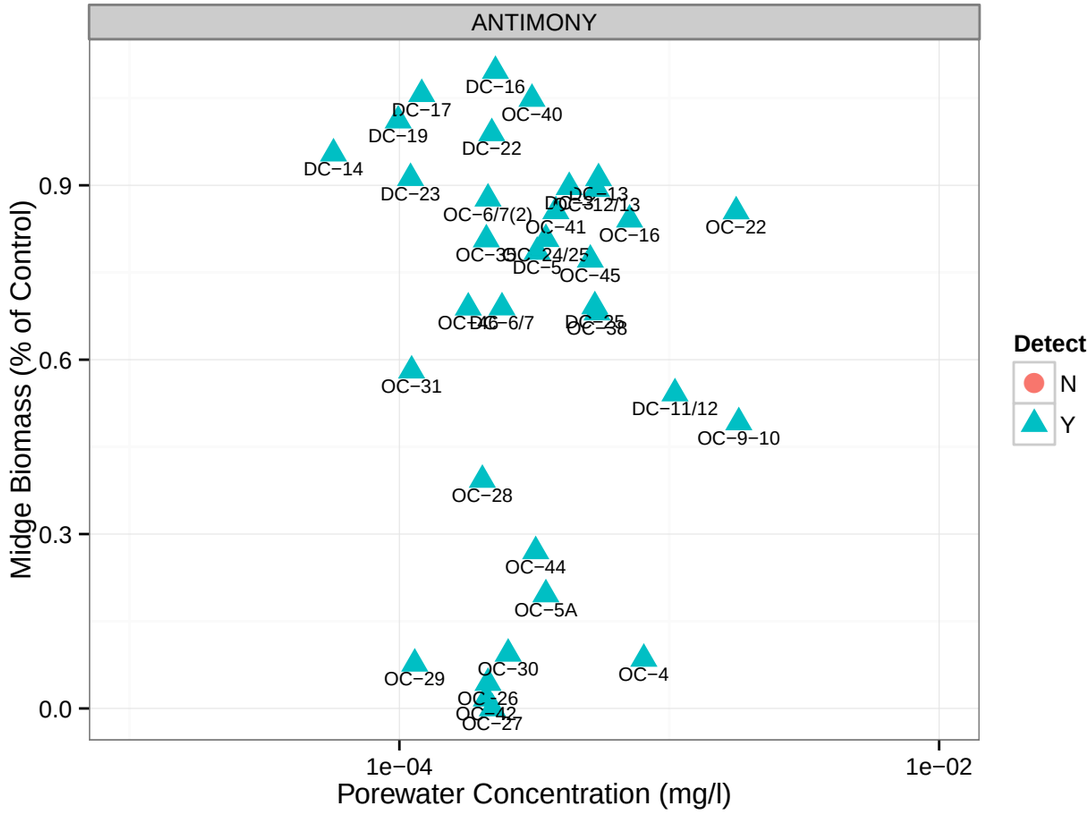

LEAD, AVS
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.01
1.00
Sediment Concentration (µmol/g)
Detect
N
Y

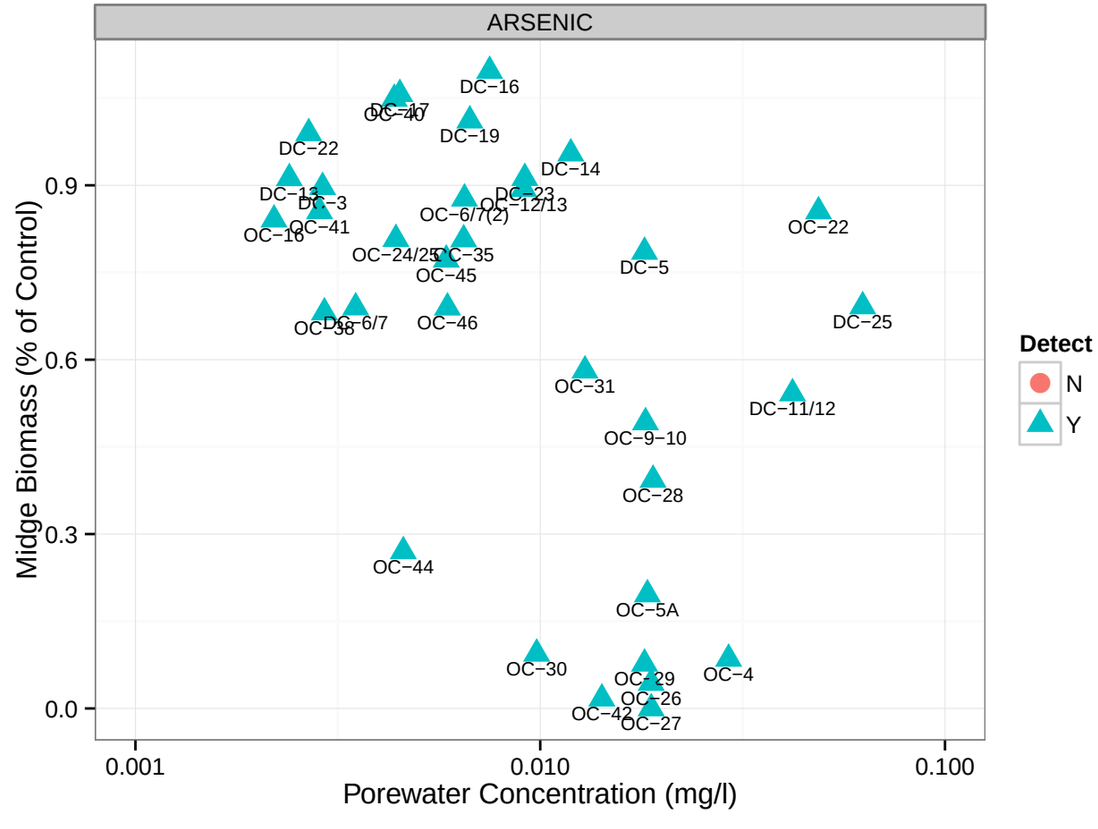

NICKEL, AVS
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.01
0.10
1.00
Sediment Concentration (µmol/g)
Detect
N
Y

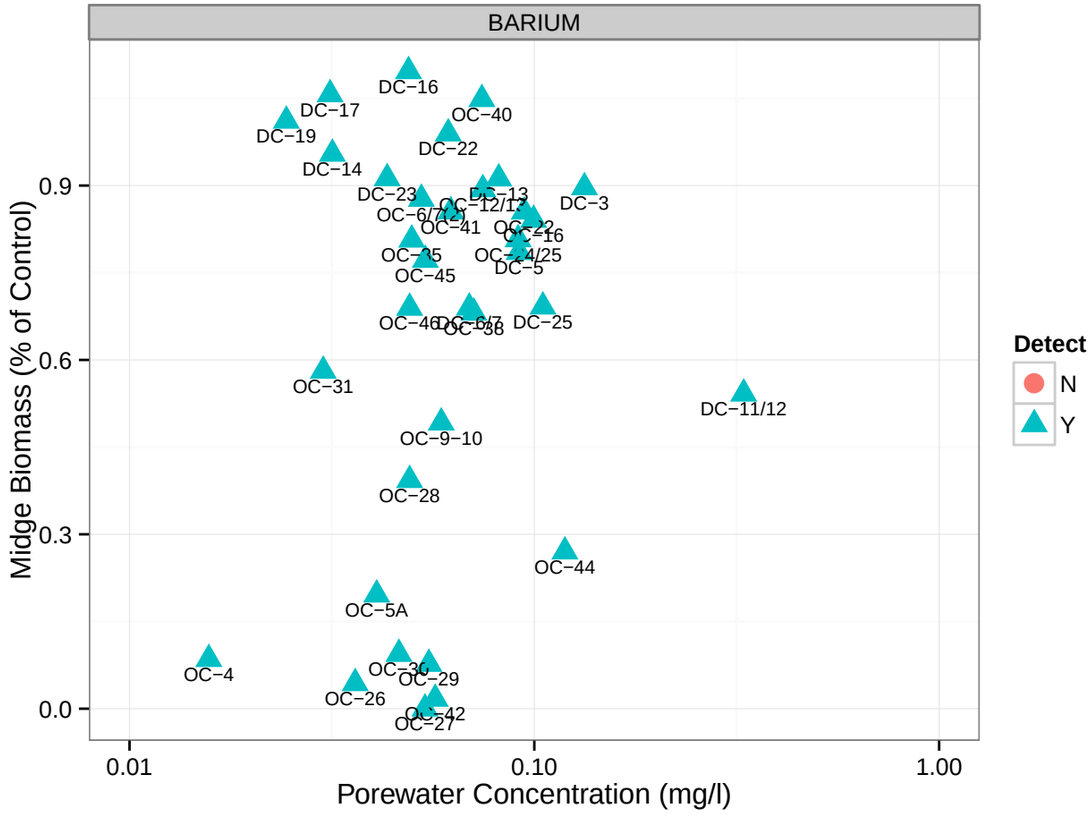

SILVER, AVS
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−03
1e−02
Sediment Concentration (µmol/g)
Detect
N
Y

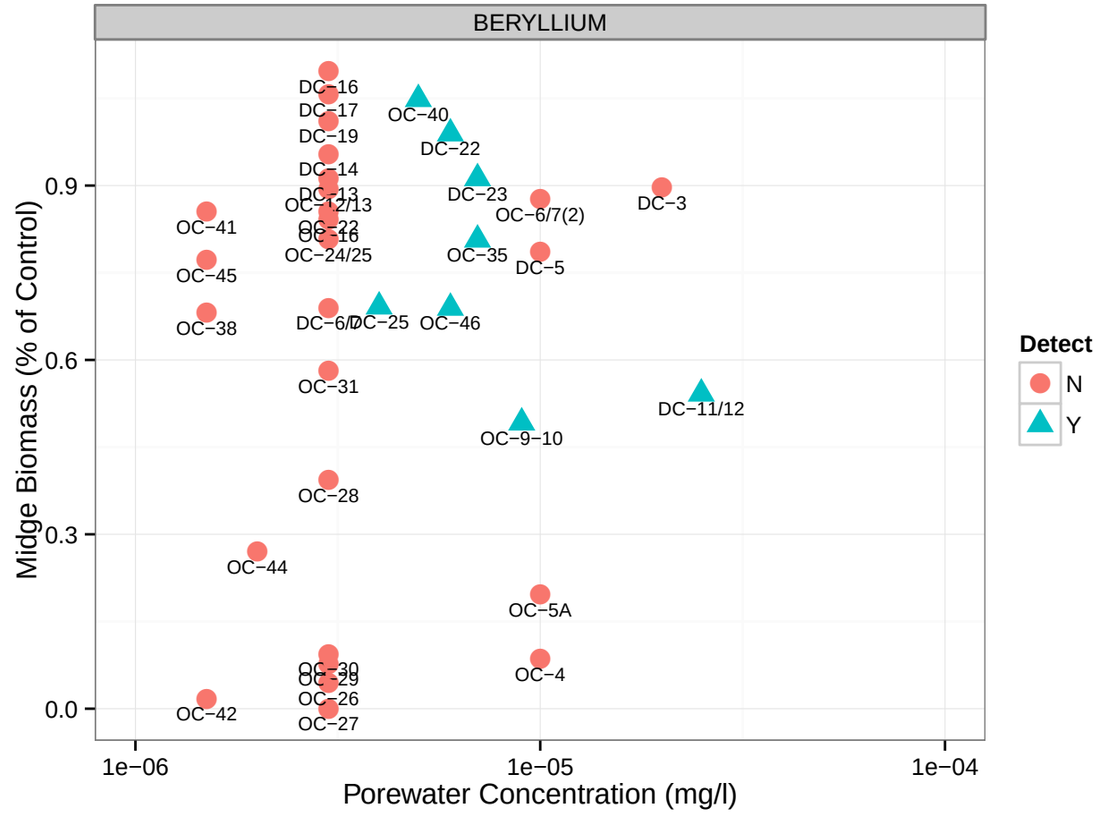

ZINC, AVS
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.1
10.0
Sediment Concentration (µmol/g)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
OC−41
OC−16
OC−24/25
OC−35
OC−45
DC−5
OC−38
OC−46
DC−25
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

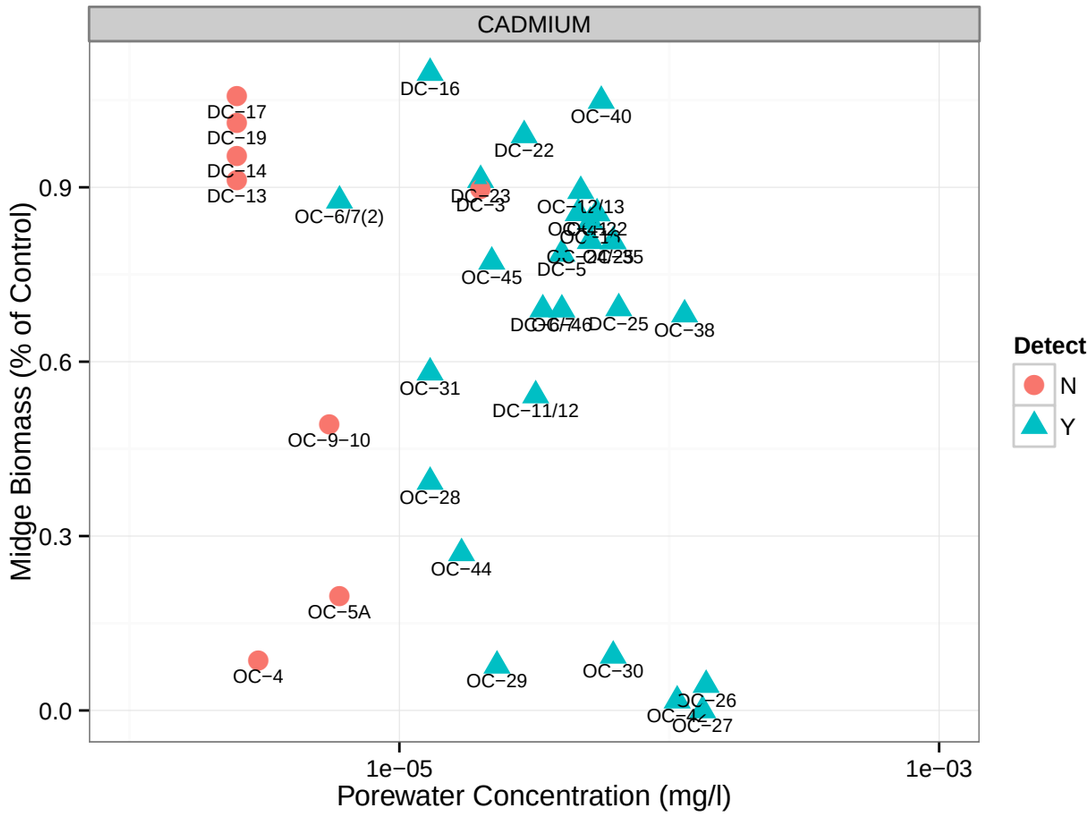

ALUMINUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.001
0.100
Porewater Concentration (mg/l)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−13
DC−3
OC−41
OC−16
OC−22
OC−24/25
OC−35
OC−45
DC−5
DC−6/7
OC−38
OC−46
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

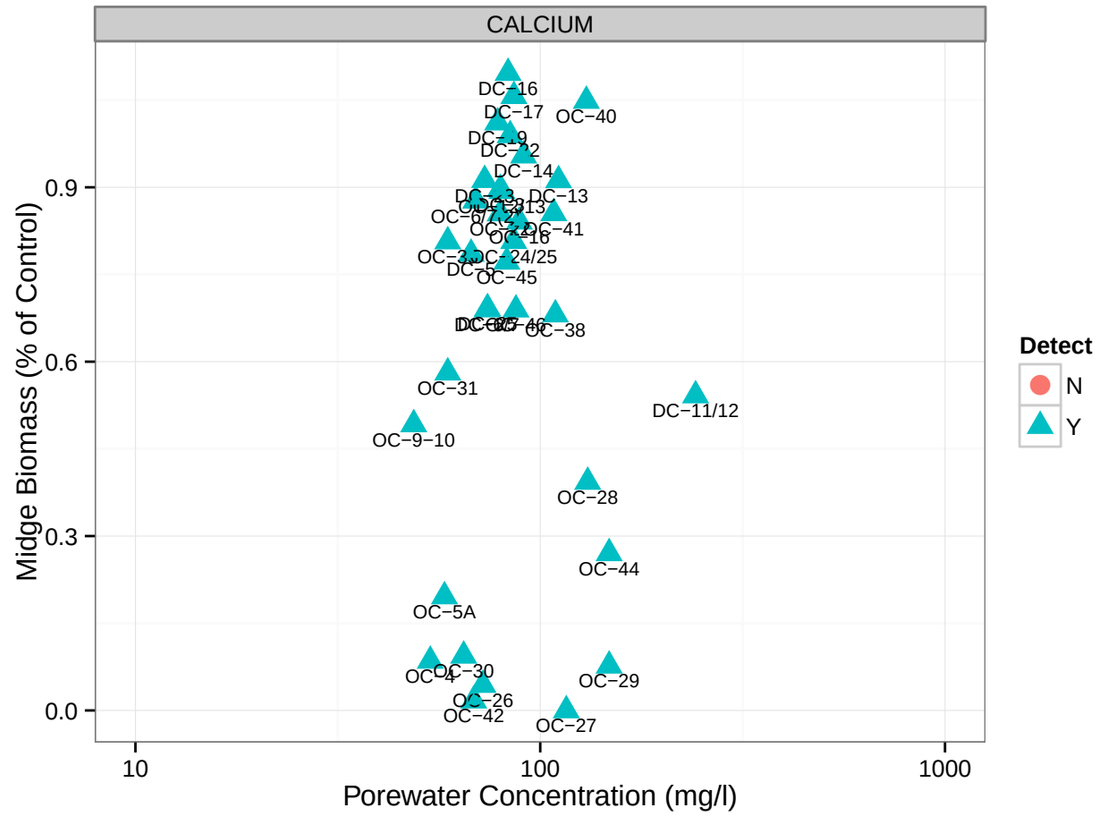

ANTIMONY
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−02
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−23
DC−13
DC−3
OC−6/7(2)
OC−12/13
OC−41
OC−16
OC−22
OC−35
OC−24/25
DC−5
OC−45
OC−46
DC−6/7
DC−25
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−30
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

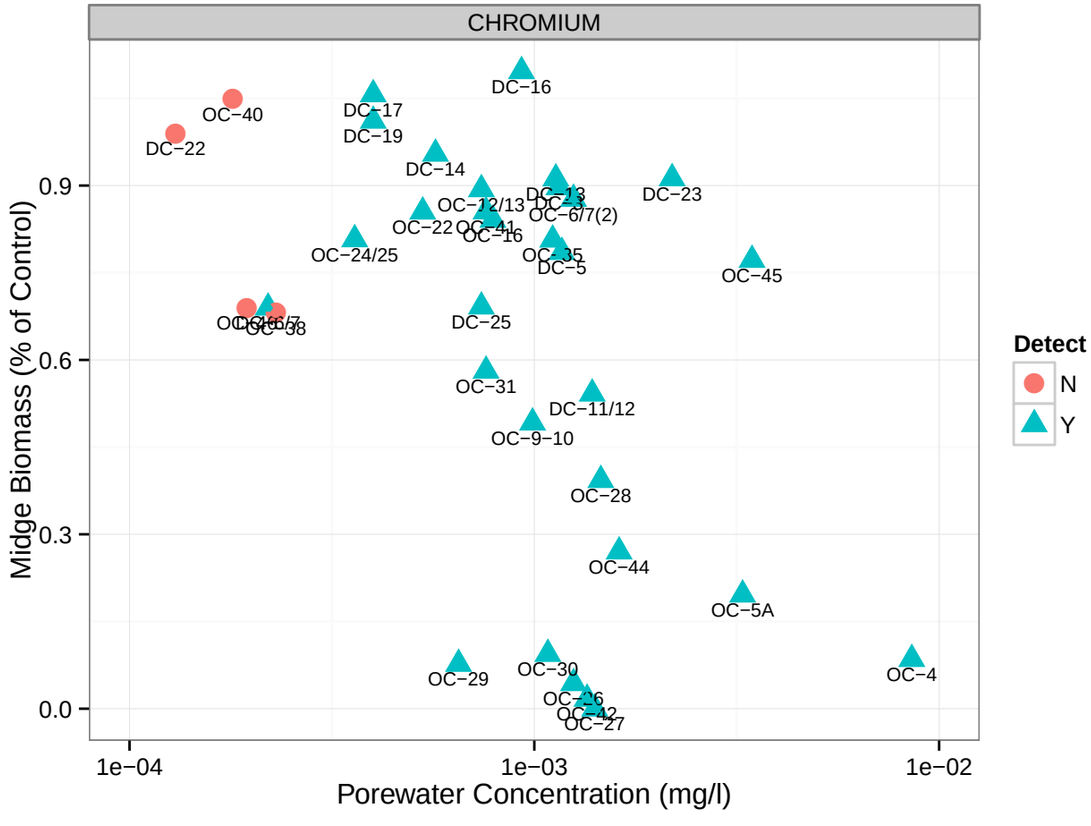

ARSENIC
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.001
0.010
0.100
Porewater Concentration (mg/l)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−13
DC−3
OC−6/7(2)
OC−12/13
OC−41
OC−16
OC−22
OC−24/25
OC−35
OC−45
DC−5
OC−38
DC−6/7
OC−46
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

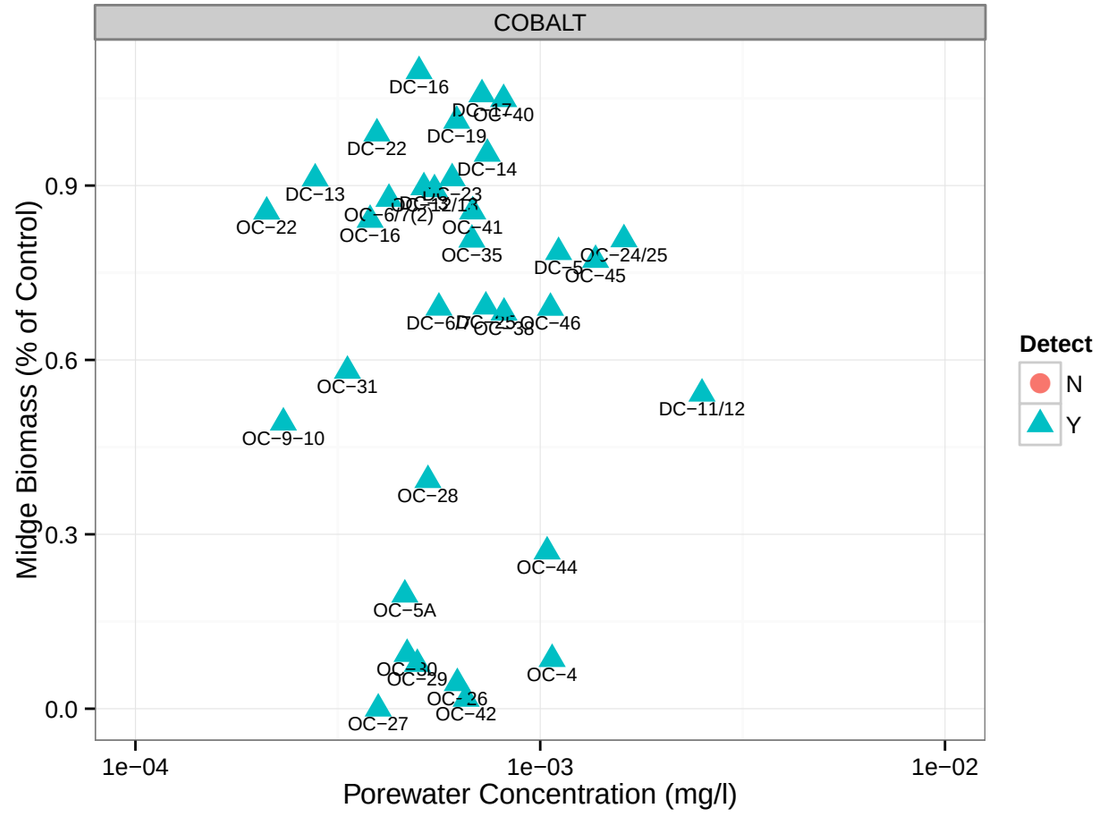

BARIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.01
0.10
1.00
Porewater Concentration (mg/l)
DC−16
DC−17
DC−19
DC−14
DC−23
DC−3
DC−22
DC−40
DC−13
OC−12/13
OC−6/7(2)
OC−41
OC−22
OC−16
OC−24/25
OC−25
OC−45
DC−5
OC−46
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

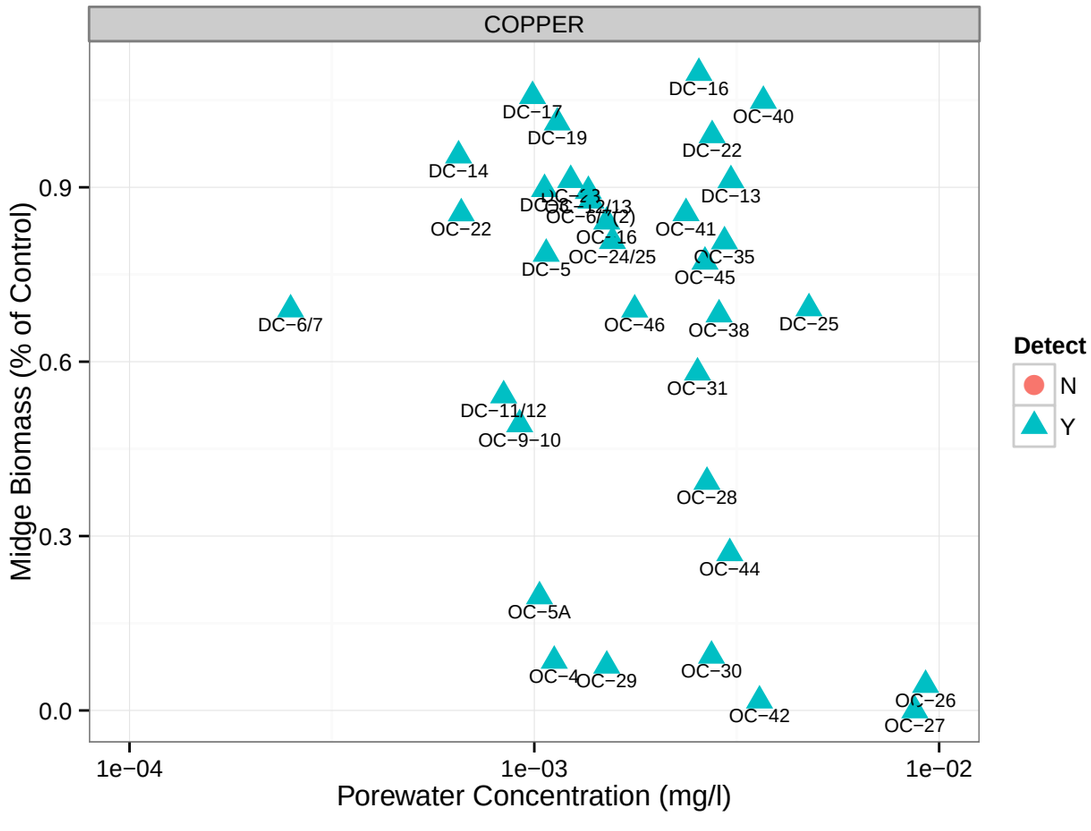

BERYLLIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−06
1e−05
1e−04
Porewater Concentration (mg/l)
DC−16
DC−17
DC−19
DC−14
DC−23
DC−3
OC−40
DC−22
OC−6/7(2)
OC−41
OC−24/25
OC−35
DC−5
OC−45
OC−38
DC−25
OC−46
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−42
OC−26
OC−27
Detect
N
Y

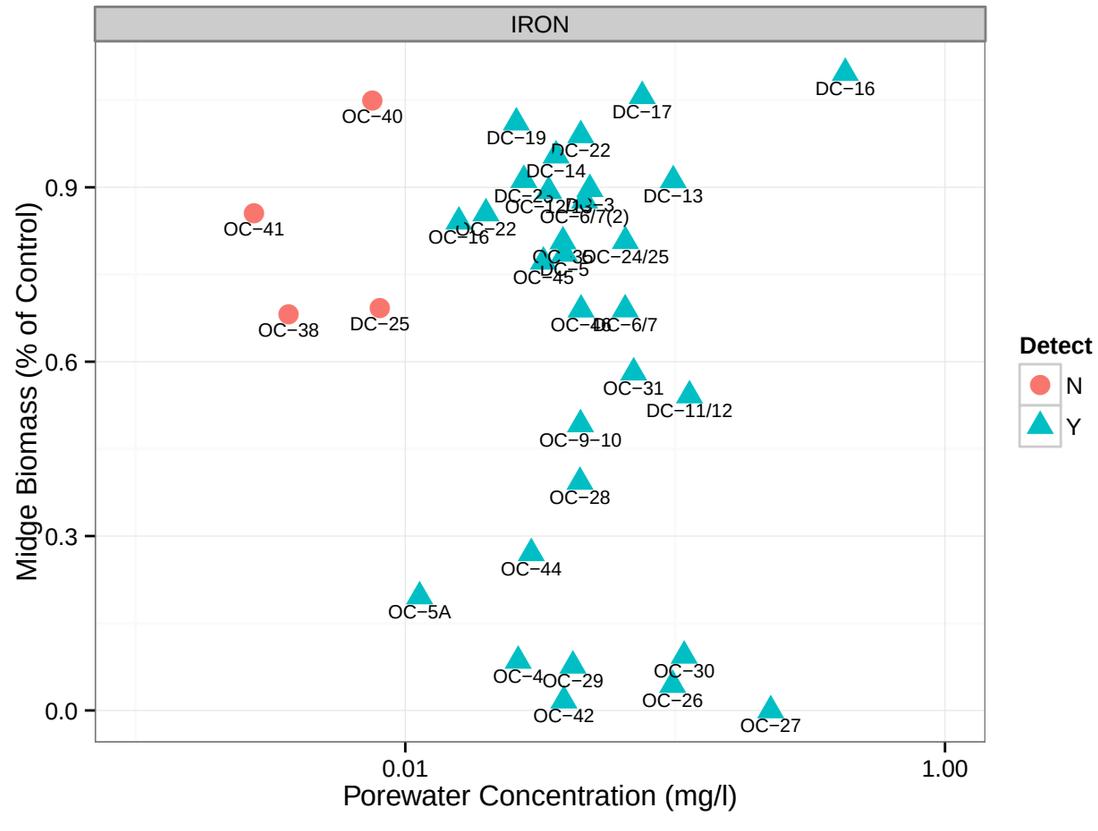

CADMIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−05
1e−03
Porewater Concentration (mg/l)
DC−16
DC−17
DC−19
DC−14
DC−13
OC−40
DC−22
DC−23
DC−3
OC−6/7(2)
OC−12/13
OC−45
DC−5
DC−25
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−26
OC−27
Detect
N
Y

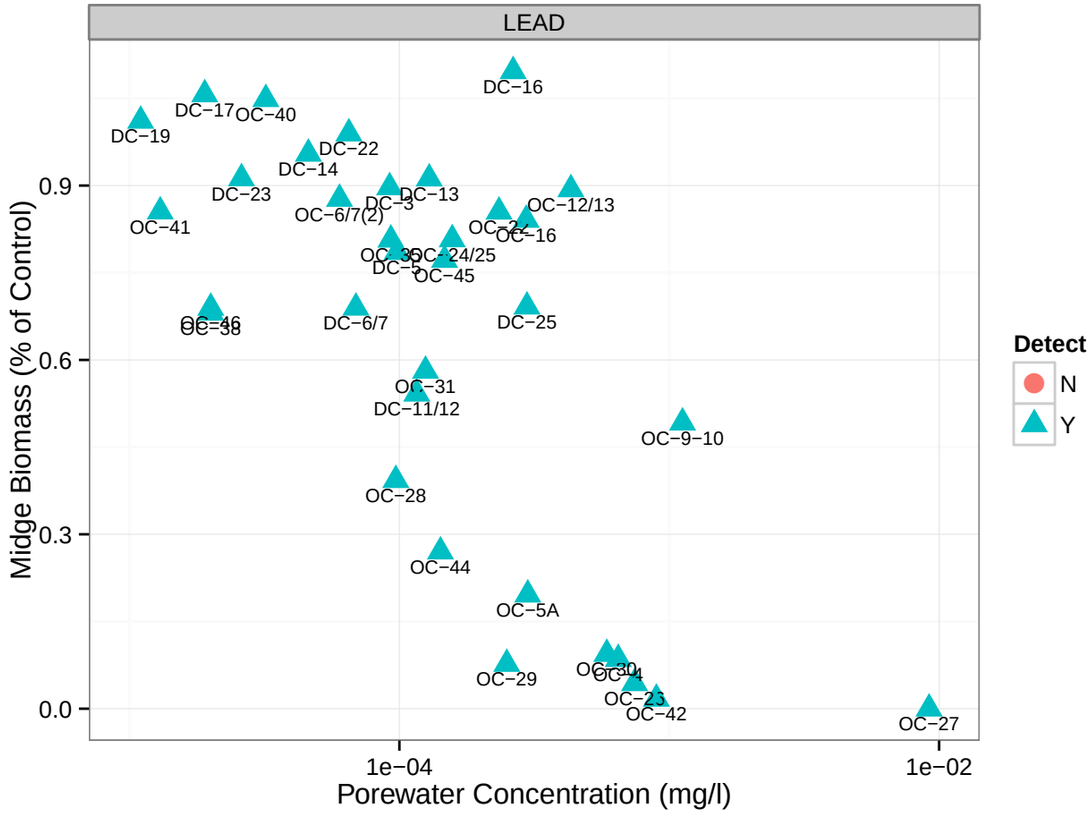

CALCIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
100
1000
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−22
DC−14
DC−13
OC−24/25
DC−5
OC−45
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

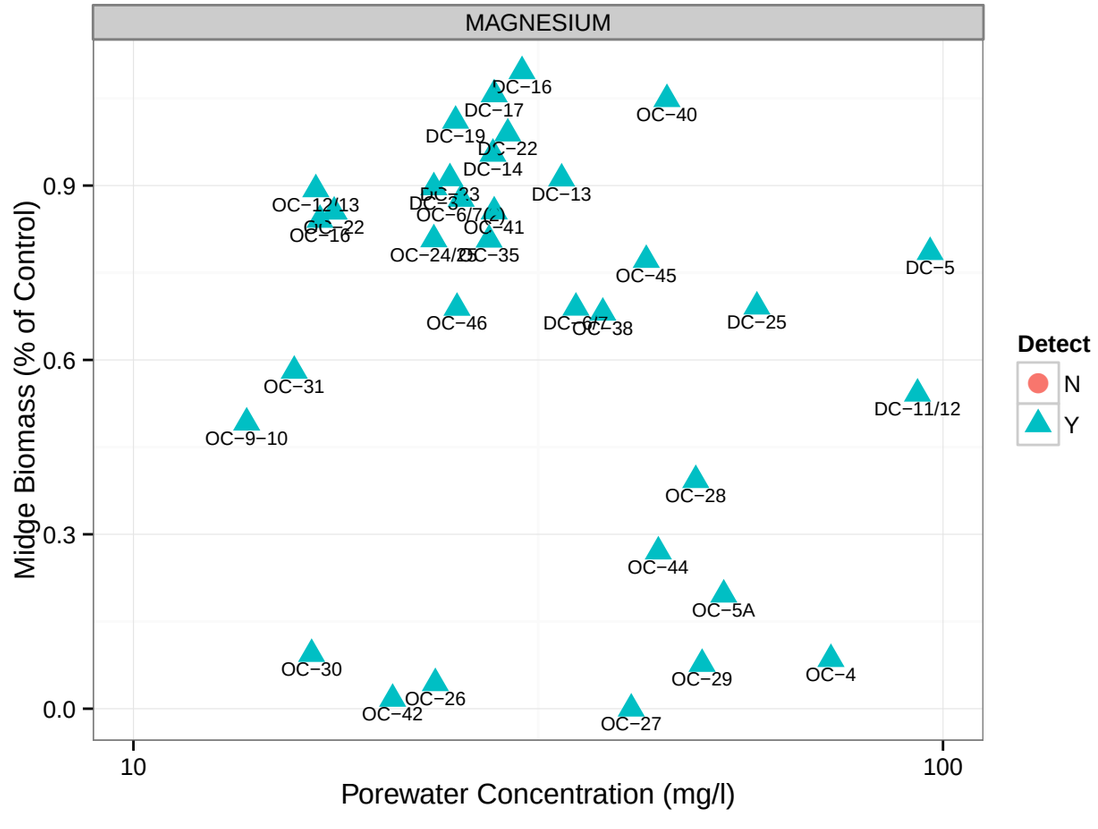

CHROMIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−13
DC−23
OC−12/13
OC−6/7(2)
OC−22
OC−41
OC−16
OC−24/25
OC−35
DC−5
OC−45
OC−46
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−30
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

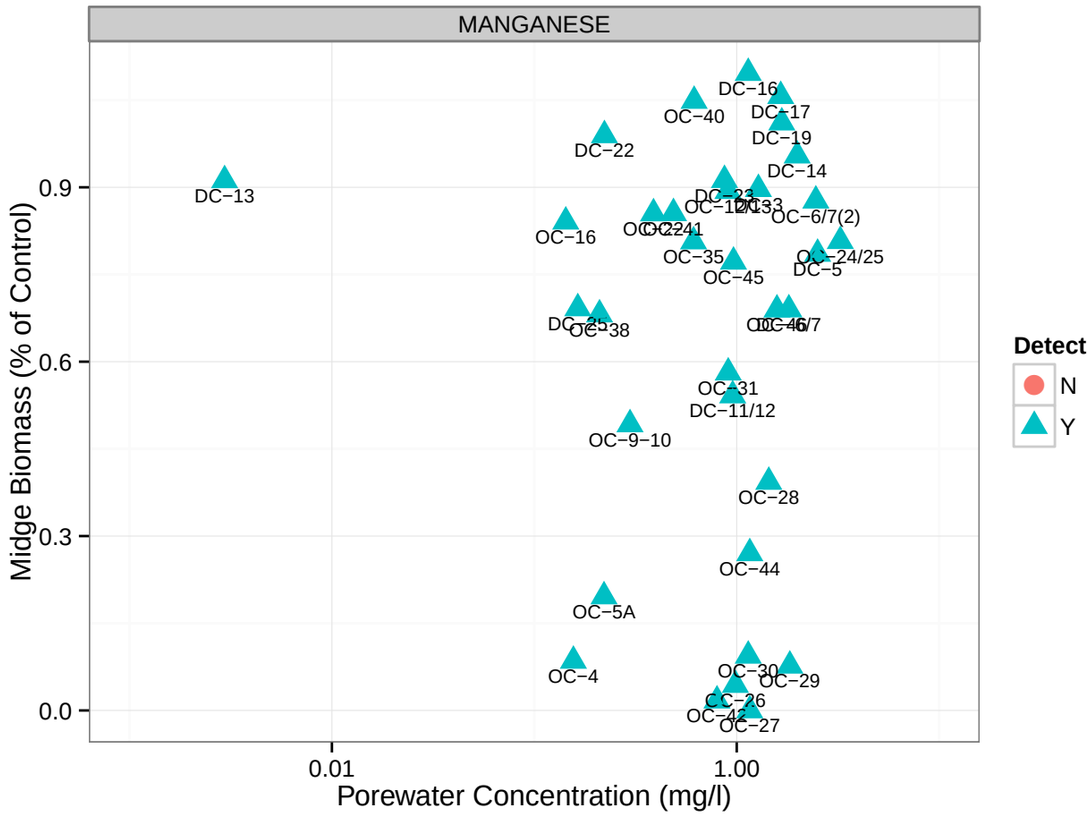

COBALT
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−13
OC−22
OC−16
OC−41
OC−35
DC−5
OC−24/25
OC−45
OC−46
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

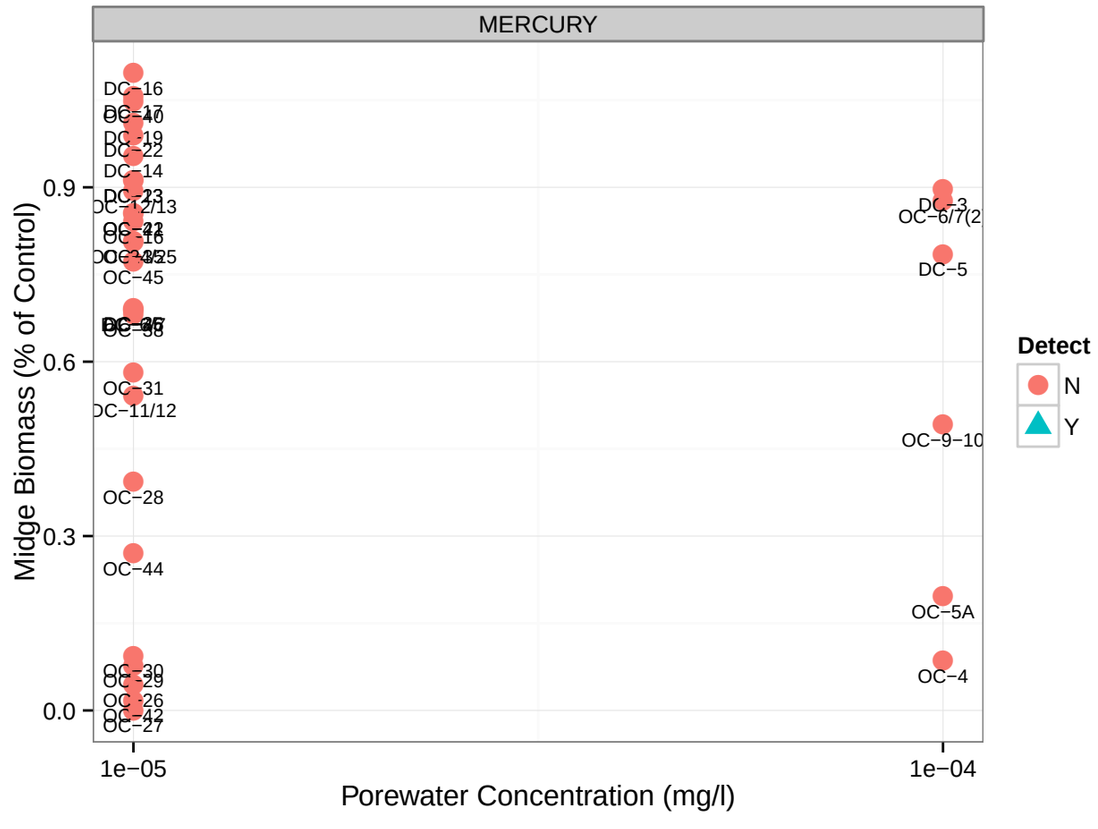

COPPER
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−13
OC−22
OC−41
OC−16
OC−24/25
OC−35
DC−5
OC−45
DC−6/7
OC−46
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−26
OC−42
OC−27
Detect
N
Y

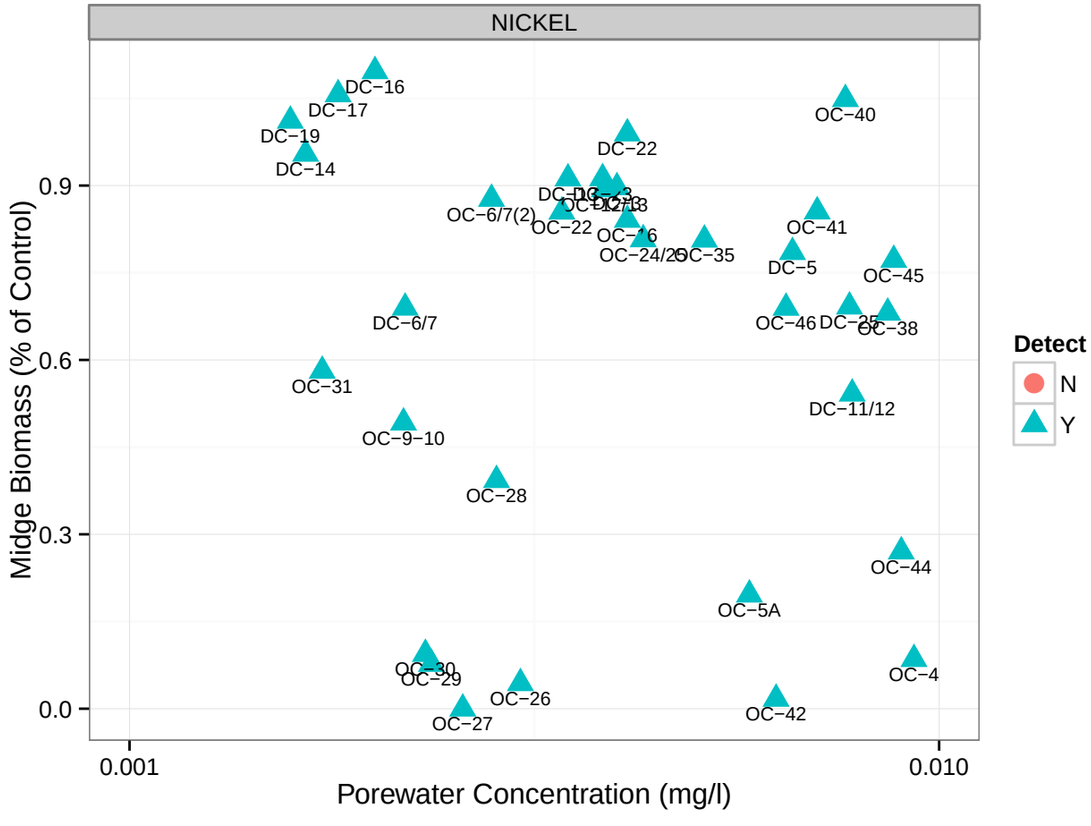

IRON
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.01
1.00
Porewater Concentration (mg/l)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−13
OC−41
OC−16
OC−22
OC−6/7(2)
OC−24/25
OC−35
DC−5
OC−45
OC−38
DC−25
OC−46
DC−6/7
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−26
OC−42
OC−27
Detect
N
Y

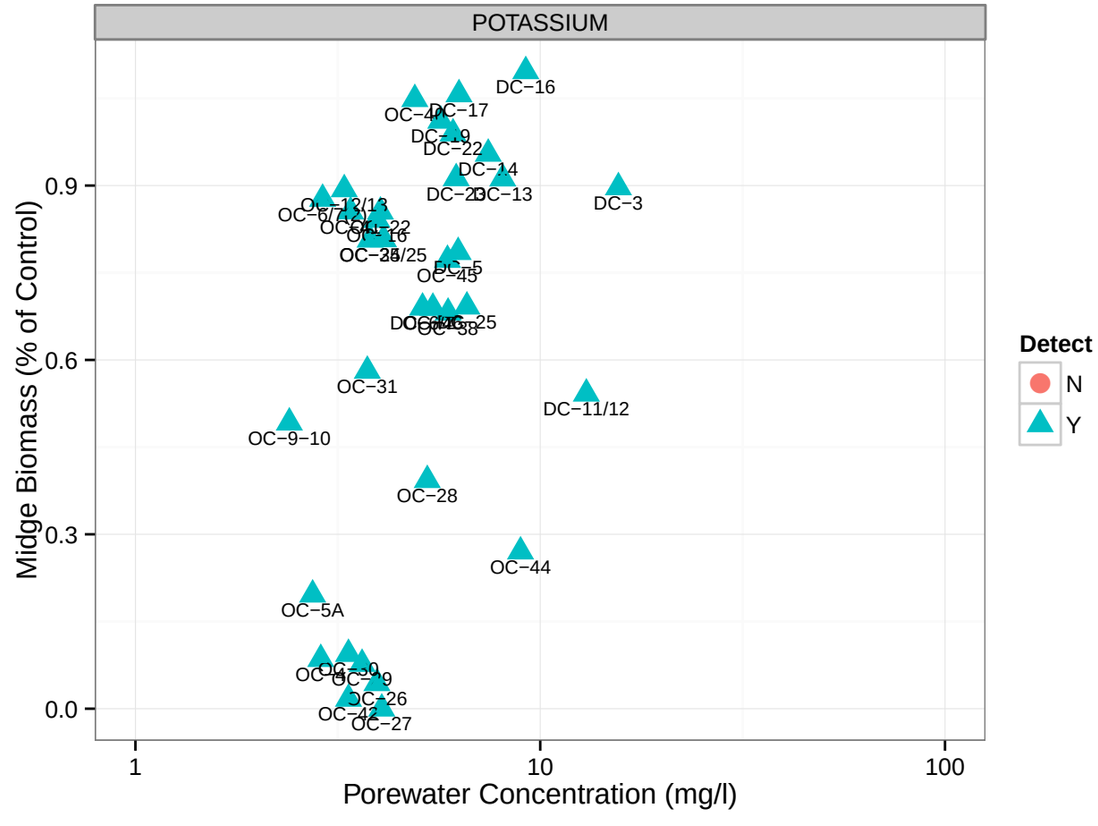

LEAD
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−02
Porewater Concentration (mg/l)
Detect
N
Y

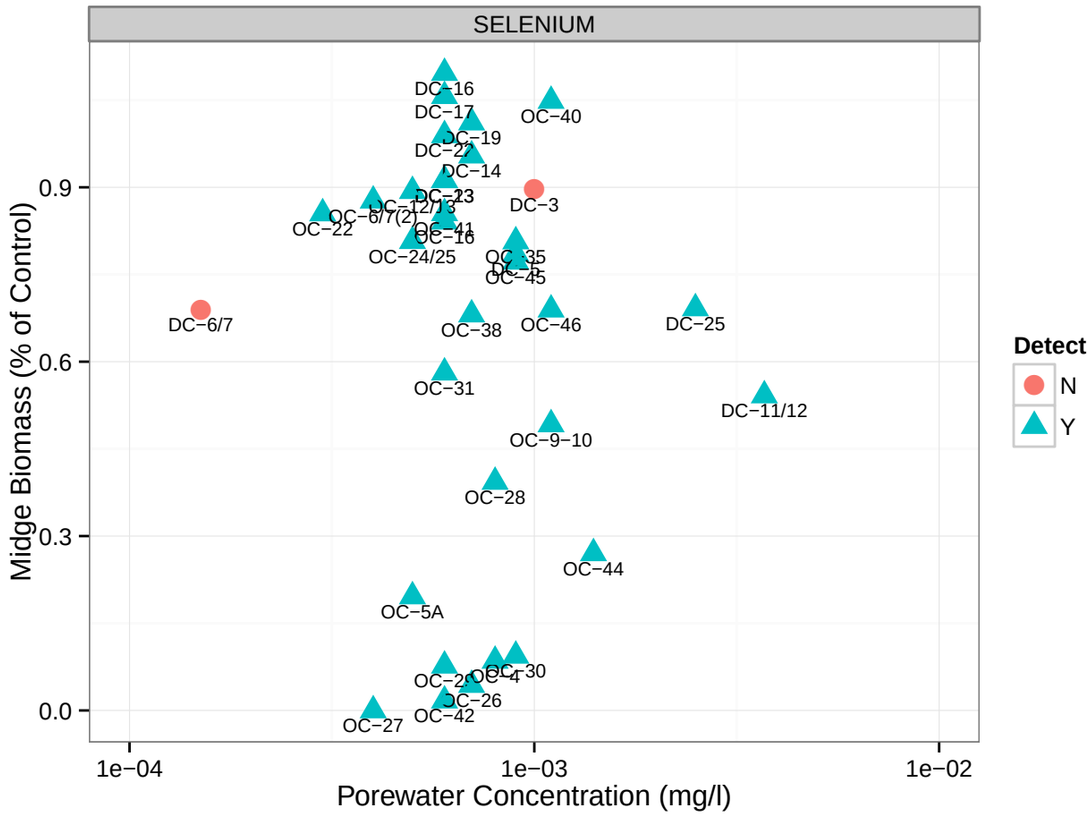

MAGNESIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
100
Porewater Concentration (mg/l)
Detect
N
Y

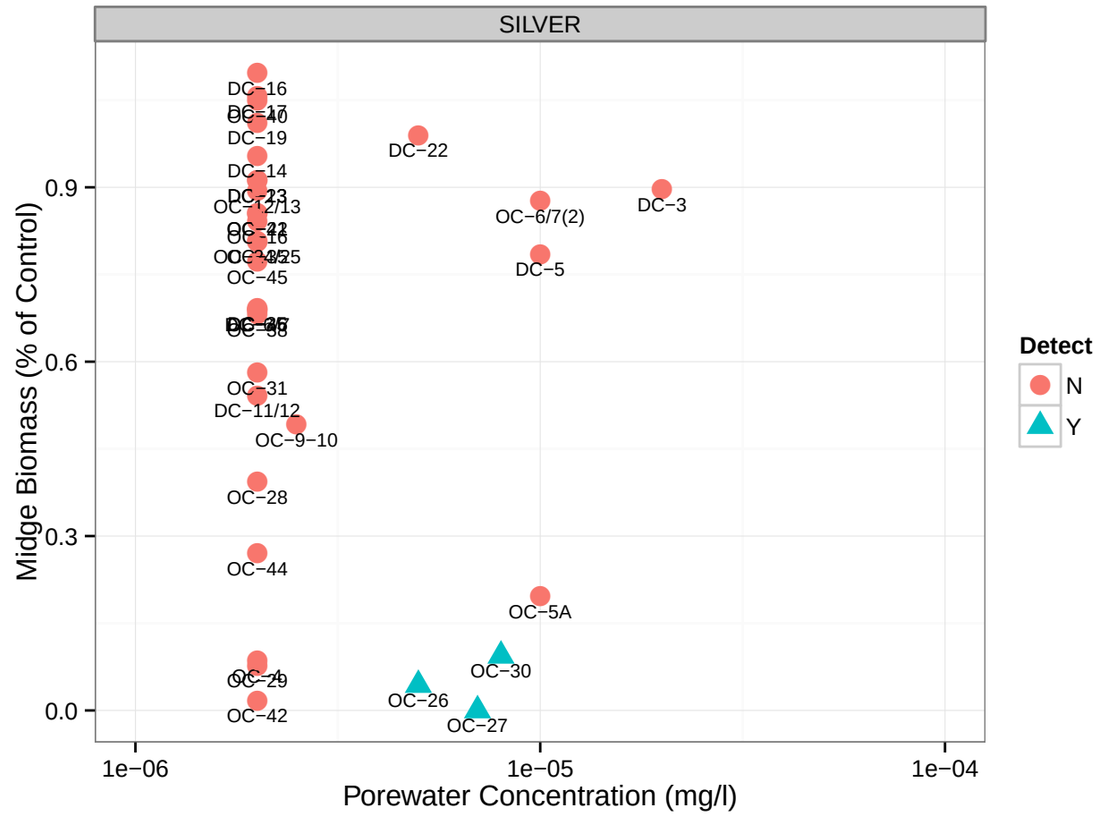

MANGANESE
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.01
1.00
Porewater Concentration (mg/l)
Detect
N
Y

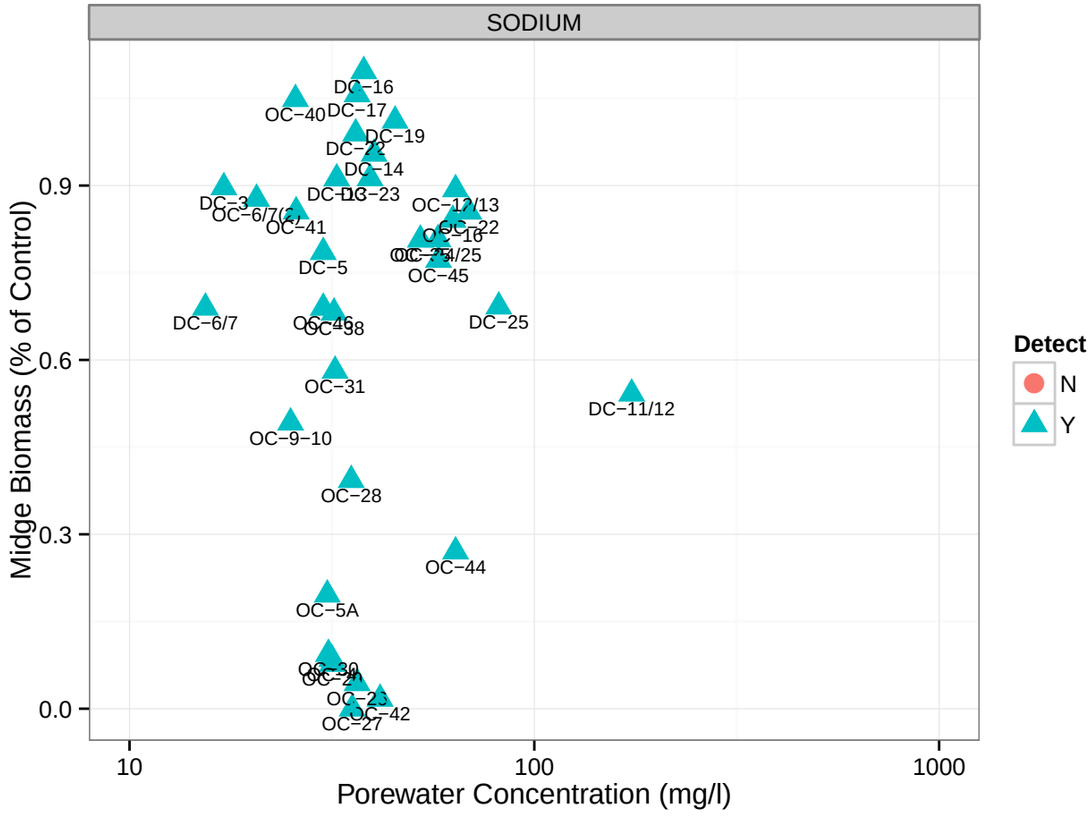

MERCURY
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−05
1e−04
Porewater Concentration (mg/l)
Detect
N
Y

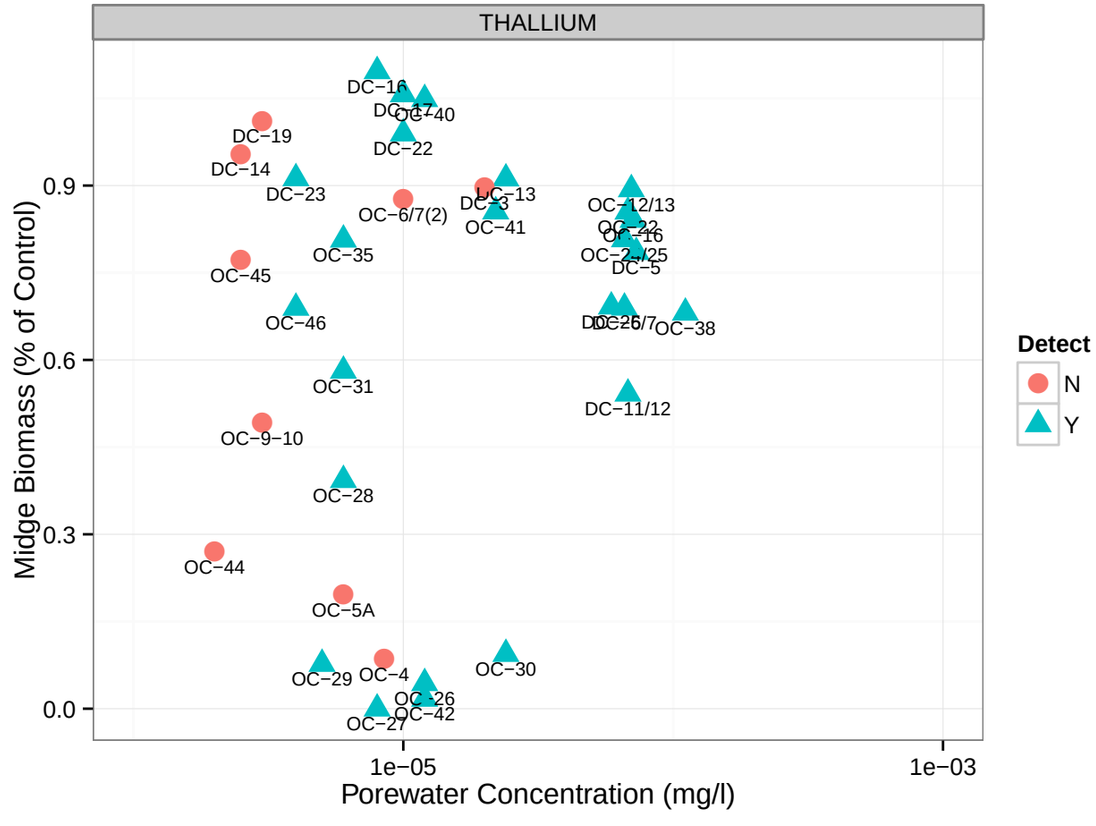

NICKEL
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.001
0.010
Porewater Concentration (mg/l)
DC−16
DC−17
DC−19
DC−14
DC−22
OC−40
OC−6/7(2)
OC−22
OC−16
OC−24/25
OC−35
OC−41
DC−5
OC−45
DC−6/7
OC−46
DC−25
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−26
OC−27
OC−42
OC−4
Detect
N
Y

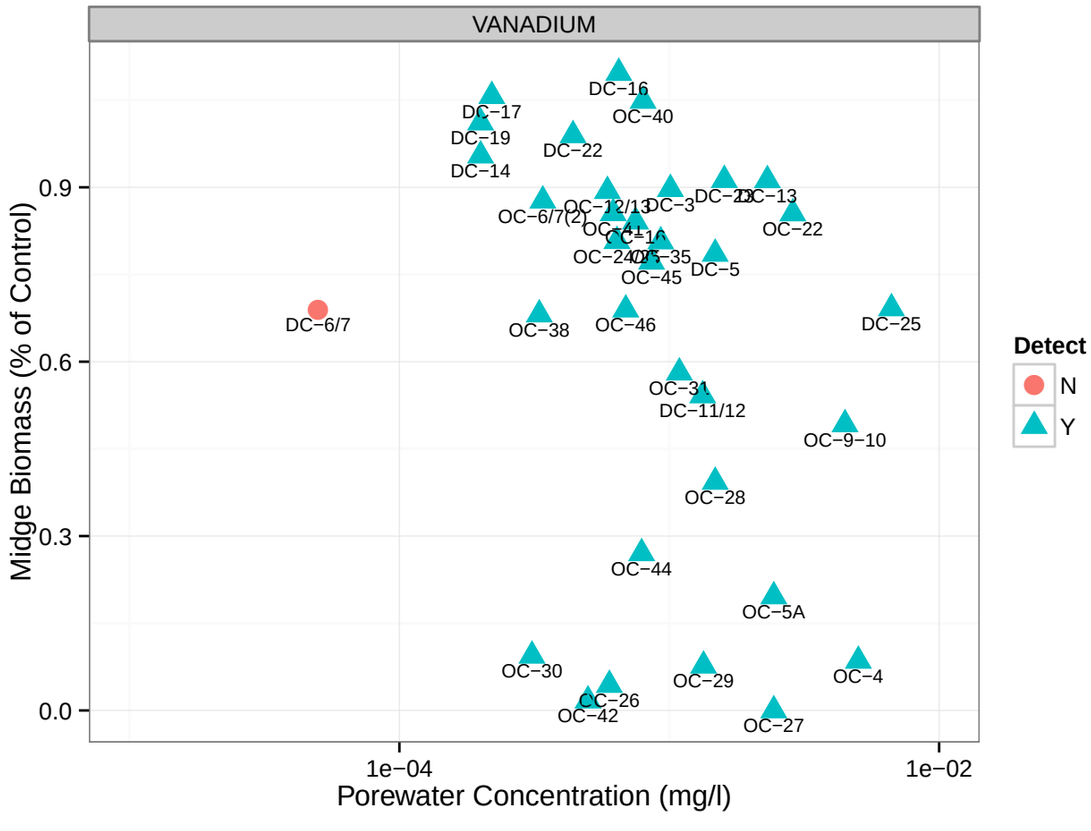

POTASSIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
10
100
Porewater Concentration (mg/l)
DC−16
DC−17
DC−22
DC−14
DC−3
DC−13
DC−5
OC−45
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−26
OC−27
Detect
N
Y

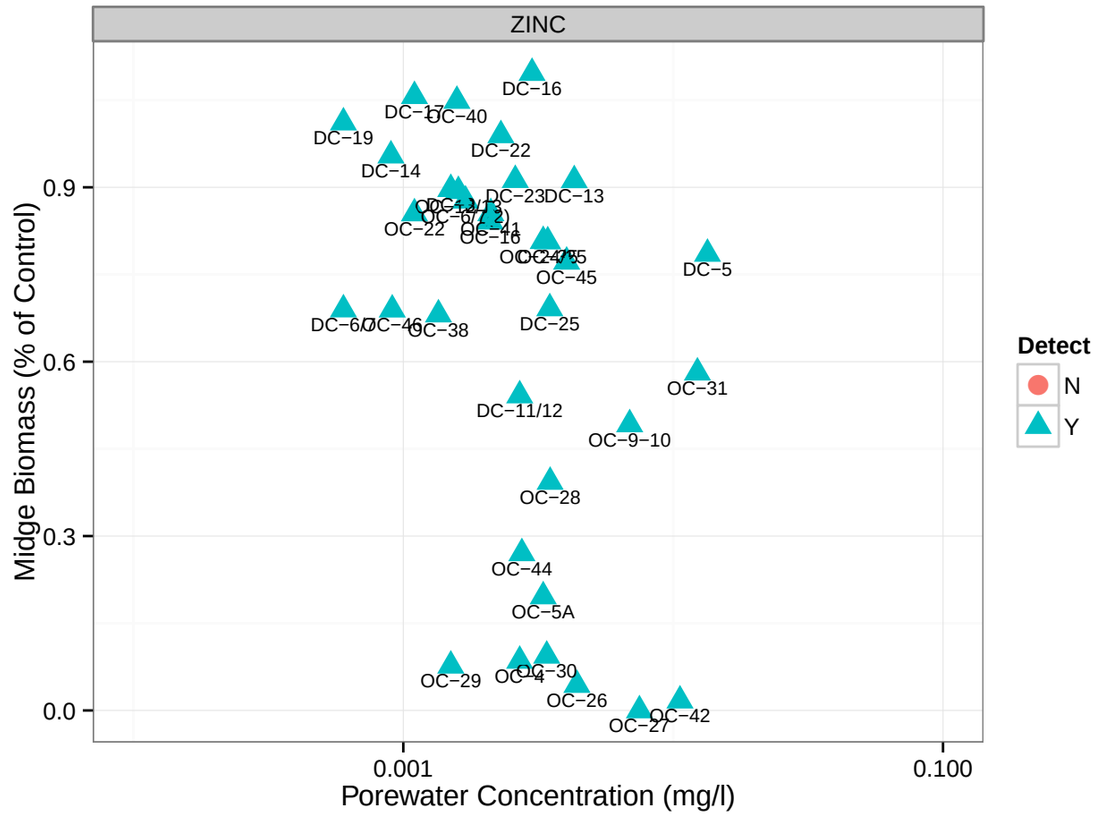

SELENIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
DC−16
DC−17
DC−19
DC−14
OC−40
DC−3
OC−6/7(2)
OC−22
OC−24/25
OC−35
OC−45
DC−6/7
OC−38
OC−46
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−26
OC−27
OC−42
Detect
N
Y

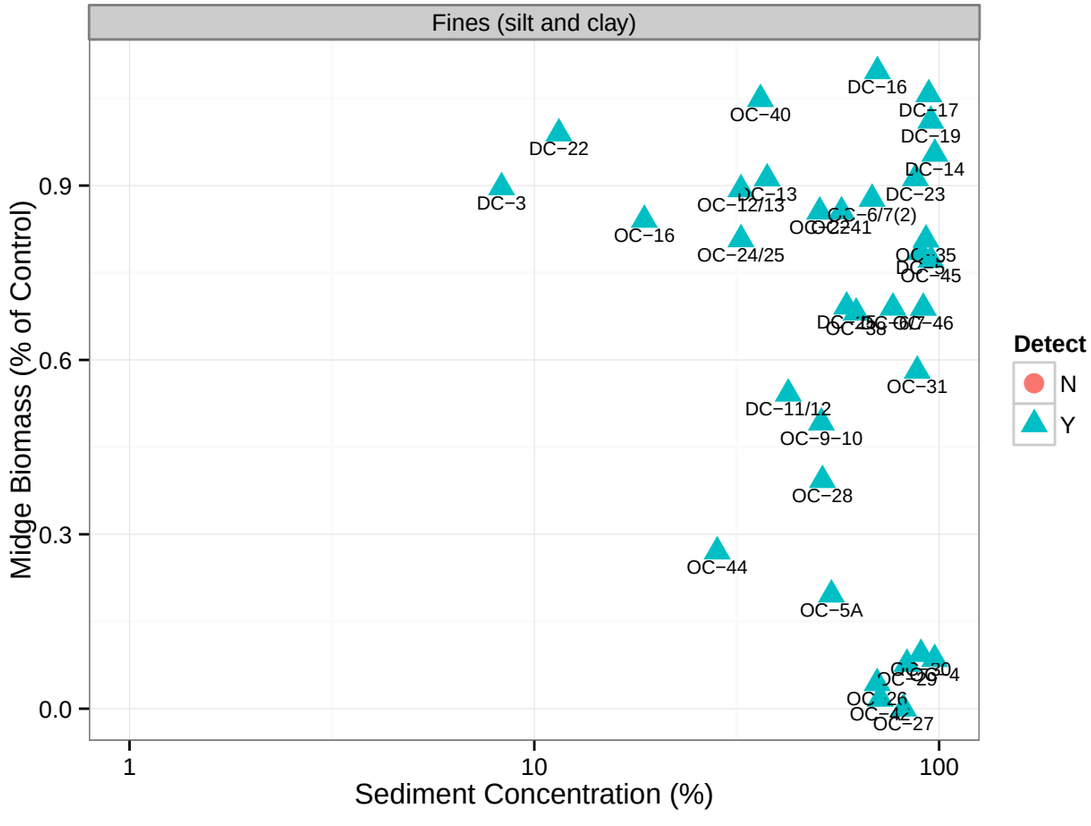

SILVER
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−06
1e−05
1e−04
Porewater Concentration (mg/l)
DC−16
DC−19
DC−22
DC−14
DC−3
OC−6/7(2)
DC−5
OC−45
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−26
OC−27
OC−42
Detect
N
Y

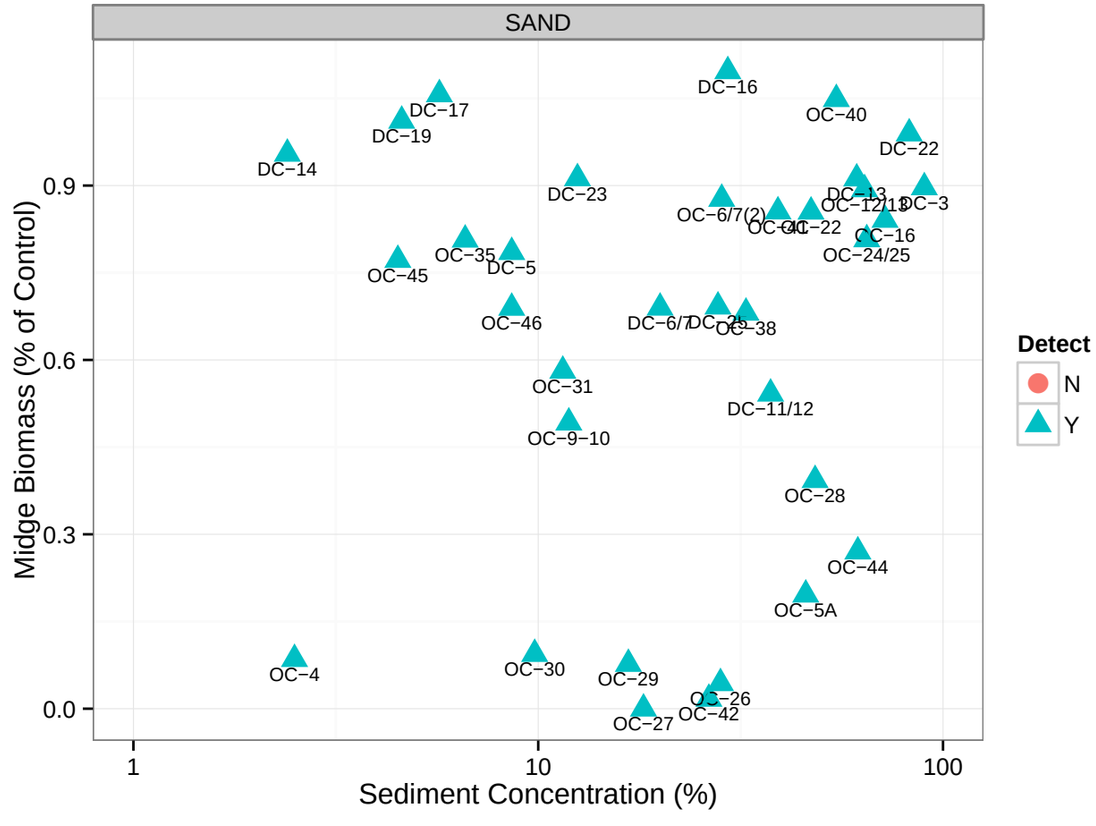

SODIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
10
100
1000
Porewater Concentration (mg/l)
DC−16
OC−40
DC−17
DC−19
DC−22
DC−14
DC−3
DC−23
OC−12/13
OC−22
OC−41
OC−16
DC−5
OC−45
DC−6/7
OC−46
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

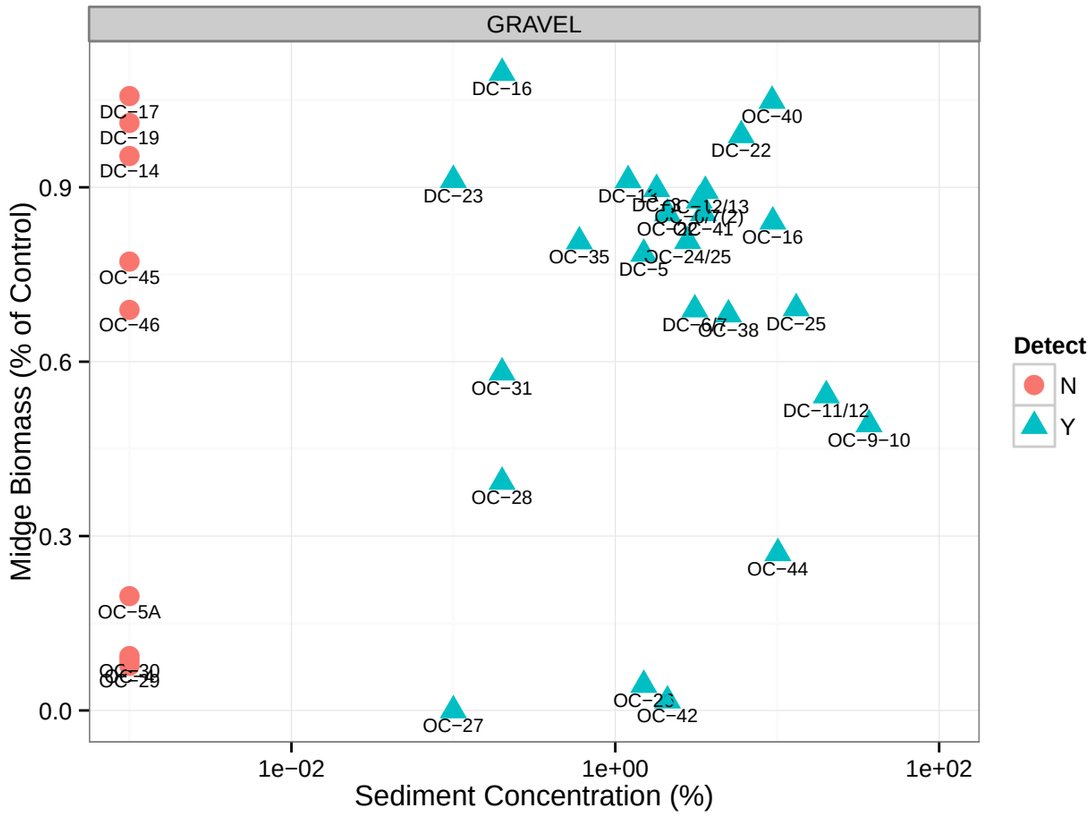

THALLIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−05
1e−03
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−23
DC−13
OC−6/7(2)
OC−41
OC−12/13
OC−22
OC−16
OC−35
DC−5
OC−45
OC−46
DC−6/7
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−4
OC−30
OC−26
OC−42
OC−27
Detect
N
Y

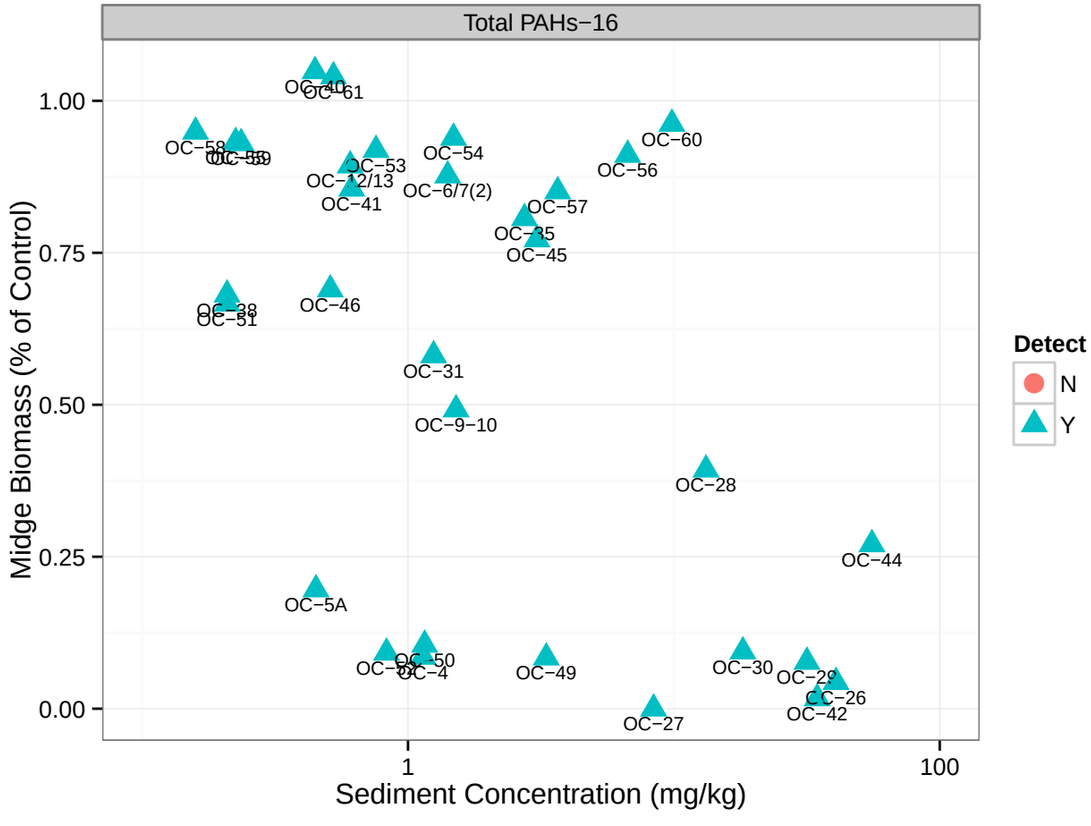

VANADIUM
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−04
1e−02
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
OC−6/7(2)
OC−12/13
DC−3
DC−23
DC−13
OC−41
OC−16
OC−22
OC−35
DC−5
OC−45
DC−6/7
OC−38
OC−46
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

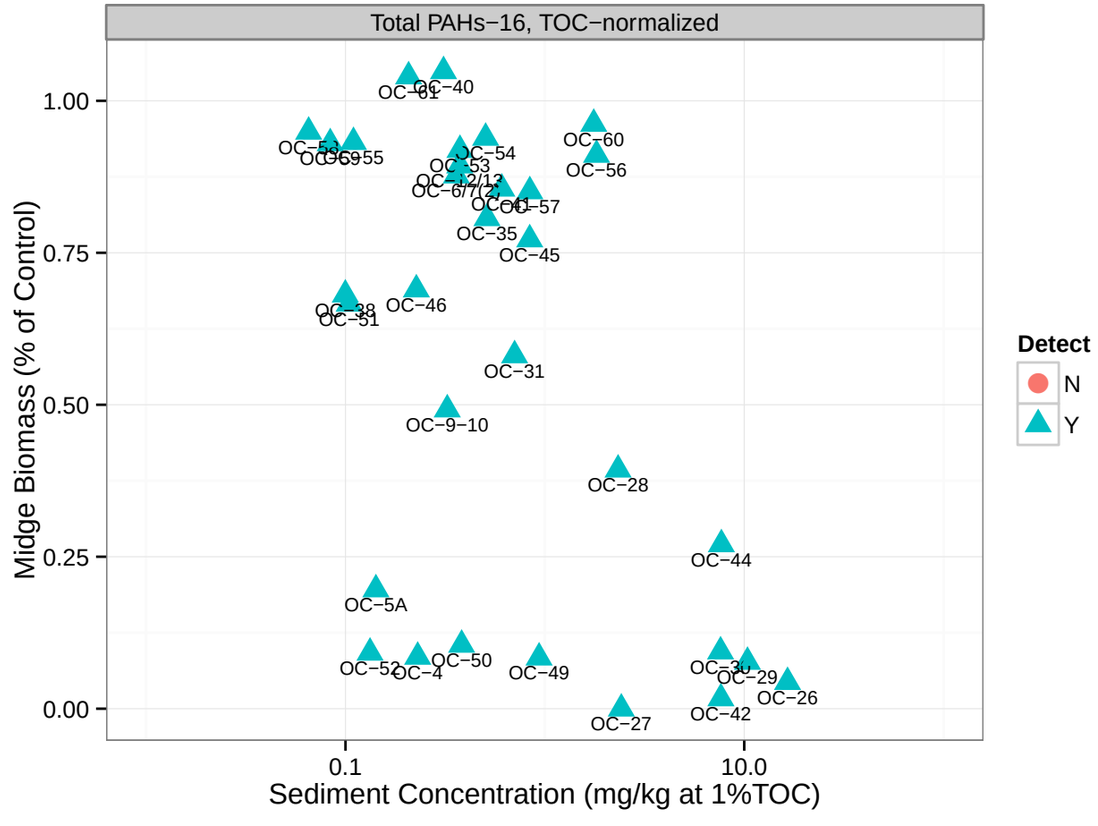

ZINC
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
0.001
0.100
Porewater Concentration (mg/l)
DC−16
DC−17
OC−40
DC−19
DC−22
DC−14
DC−23
DC−13
OC−6/7(2)
OC−41
OC−16
OC−22
OC−45
DC−5
DC−6/7
OC−46
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−4
OC−30
OC−26
OC−42
OC−27
Detect
N
Y

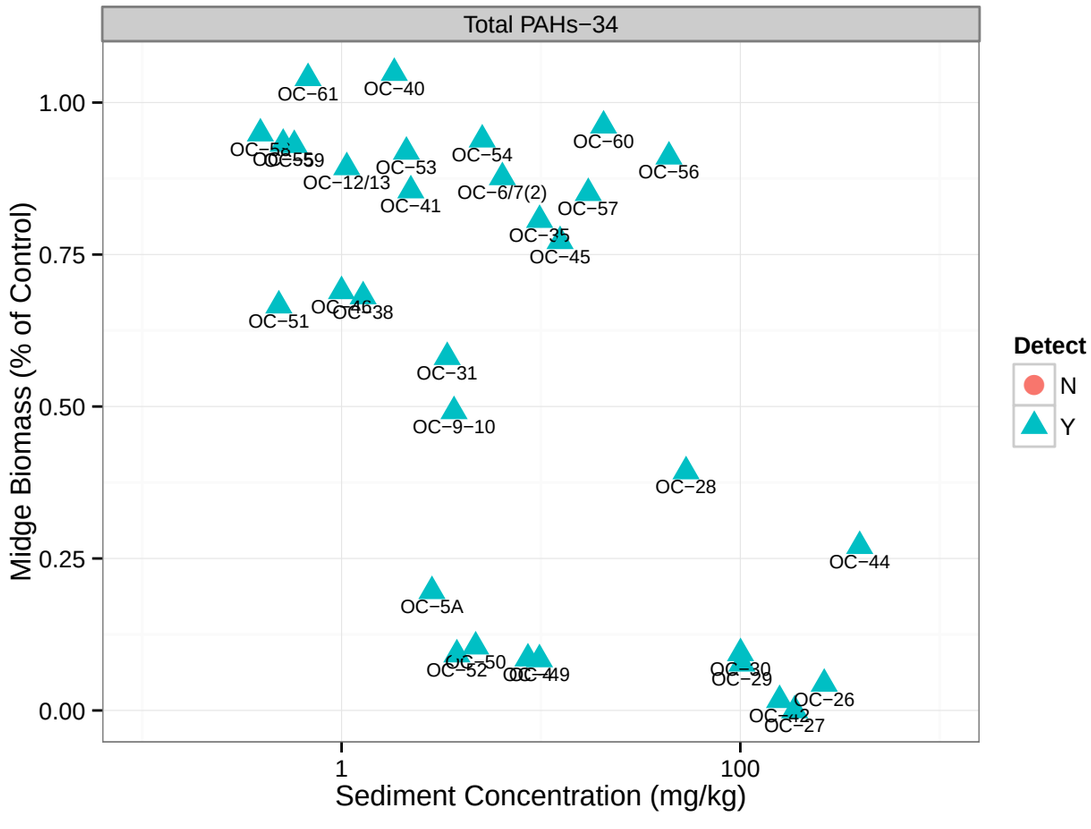

Fines (silt and clay)
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
10
100
Sediment Concentration (%)
DC−16
DC−17
DC−19
DC−14
DC−22
DC−3
OC−40
DC−13
OC−12/13
DC−23
OC−6/7(2)
OC−41
OC−16
OC−24/25
OC−35
DC−5
OC−45
OC−46
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

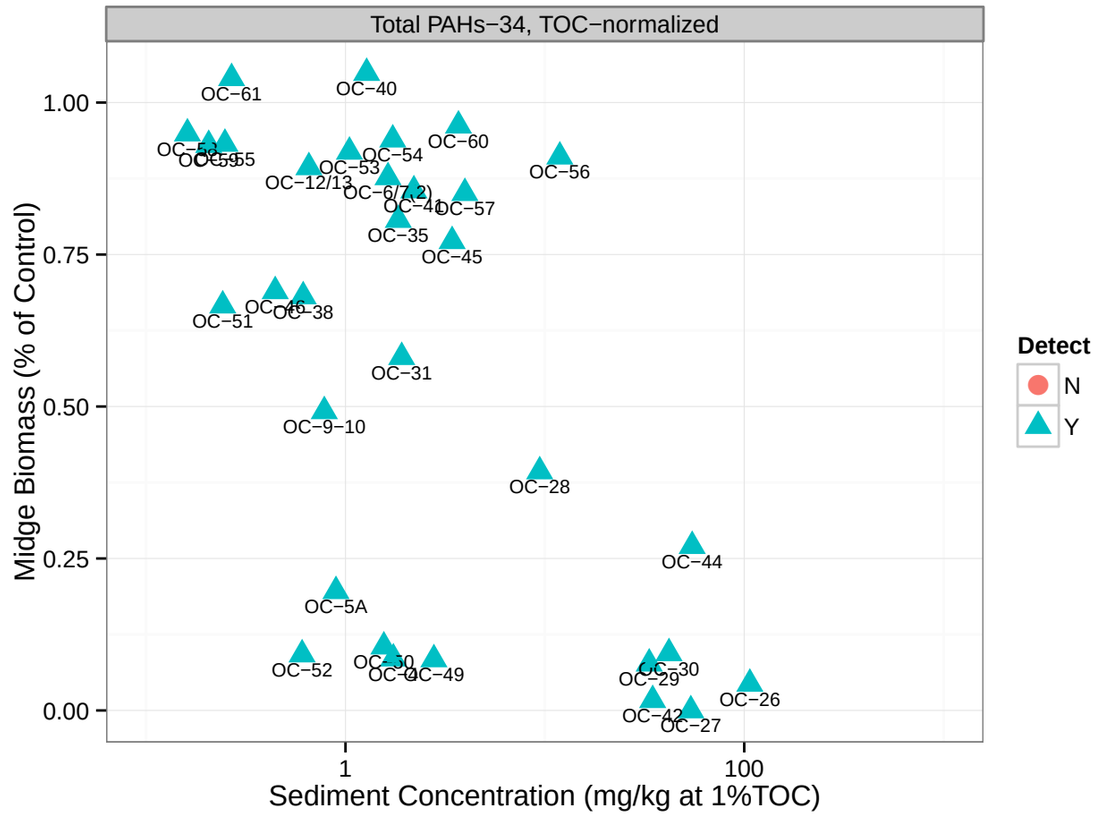

SAND
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1
10
100
Sediment Concentration (%)
DC−16
DC−17
DC−19
DC−14
DC−23
OC−40
DC−22
DC−3
OC−6/7(2)
OC−12/13
OC−16
OC−24/25
OC−35
DC−5
OC−45
OC−46
OC−38
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

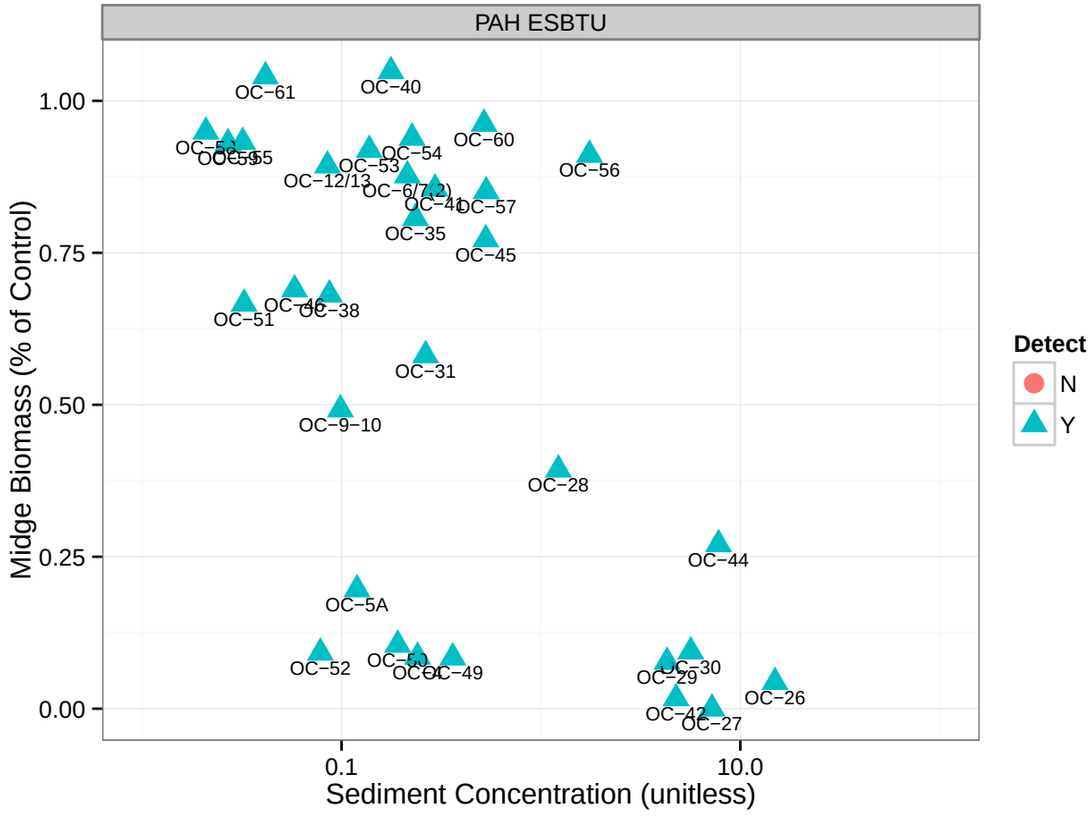

GRAVEL
Midge Biomass (% of Control)
0.0
0.3
0.6
0.9
1e−02
1e+00
1e+02
Sediment Concentration (%)
DC−16
DC−17
DC−19
DC−14
DC−23
OC−40
DC−22
OC−12/13
OC−16
OC−35
DC−5
OC−24/25
OC−45
OC−46
OC−38
DC−25
OC−31
DC−11/12
OC−9−10
OC−28
OC−44
OC−5A
OC−27
OC−42
Detect
N
Y

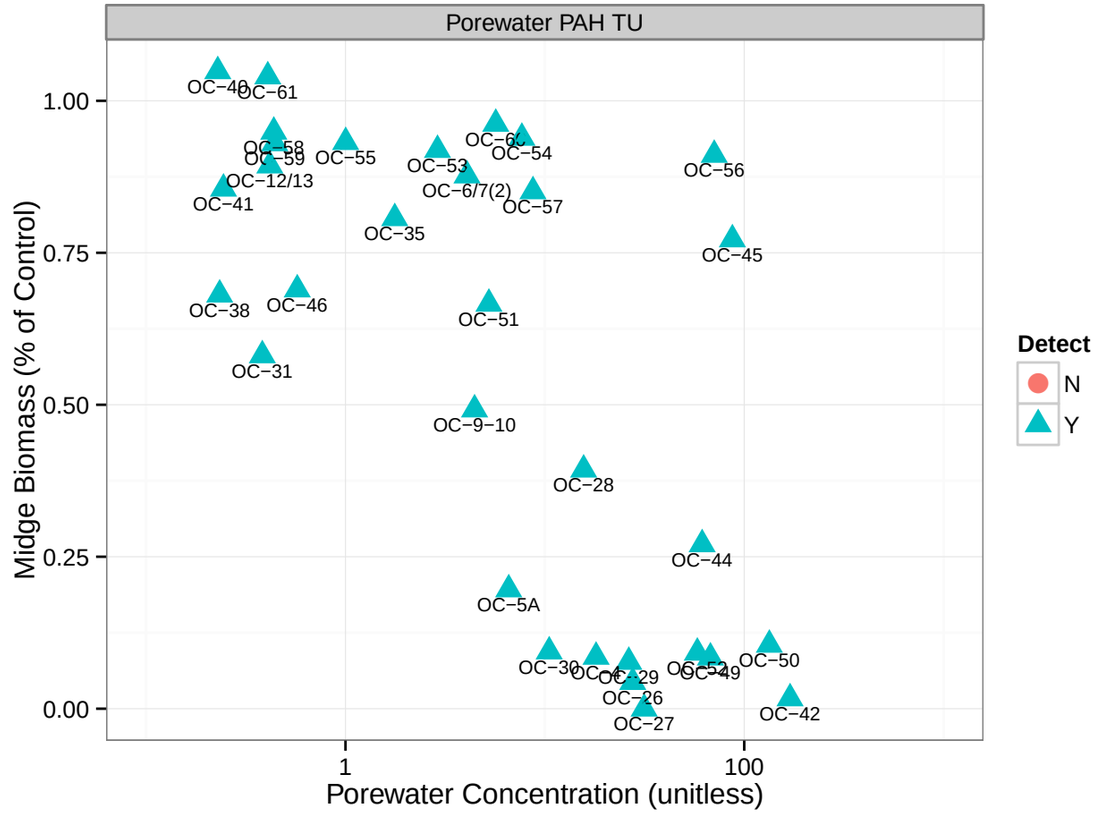

Total PAHs−16
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
100
Sediment Concentration (mg/kg)
Detect
N
Y

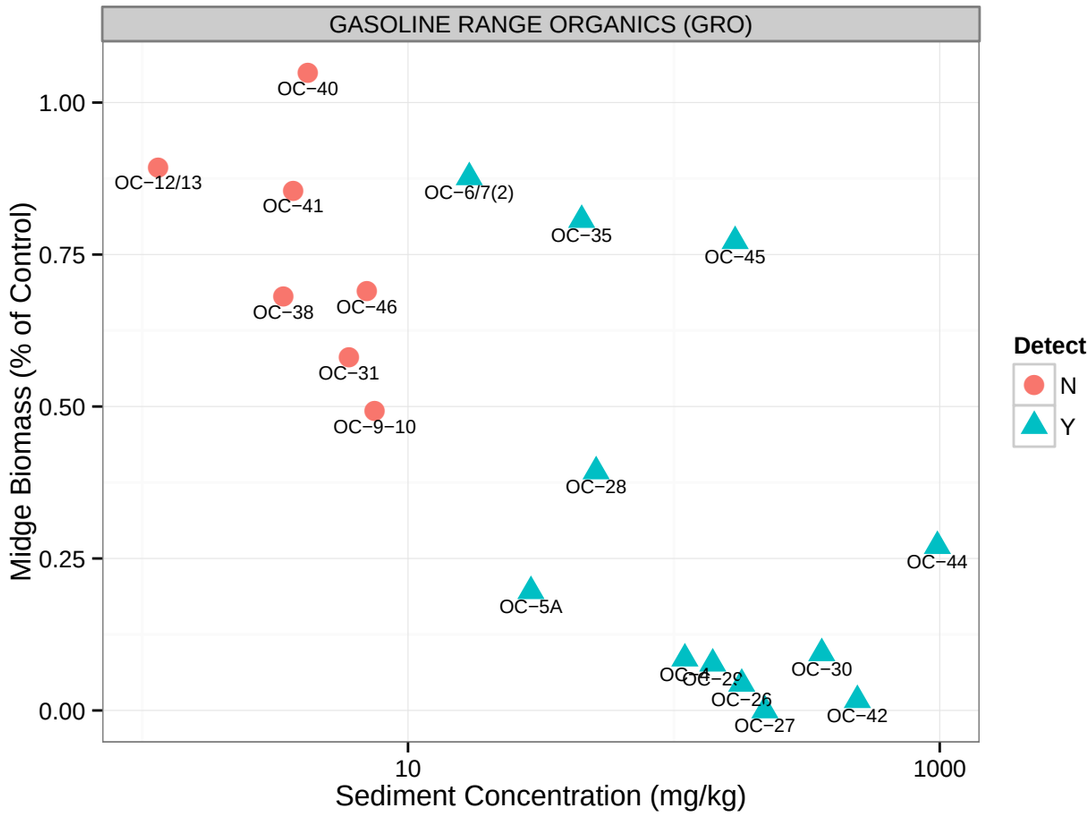

Total PAHs−16, TOC−normalized
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.1
10.0
Sediment Concentration (mg/kg at 1%TOC)
Detect
N
Y

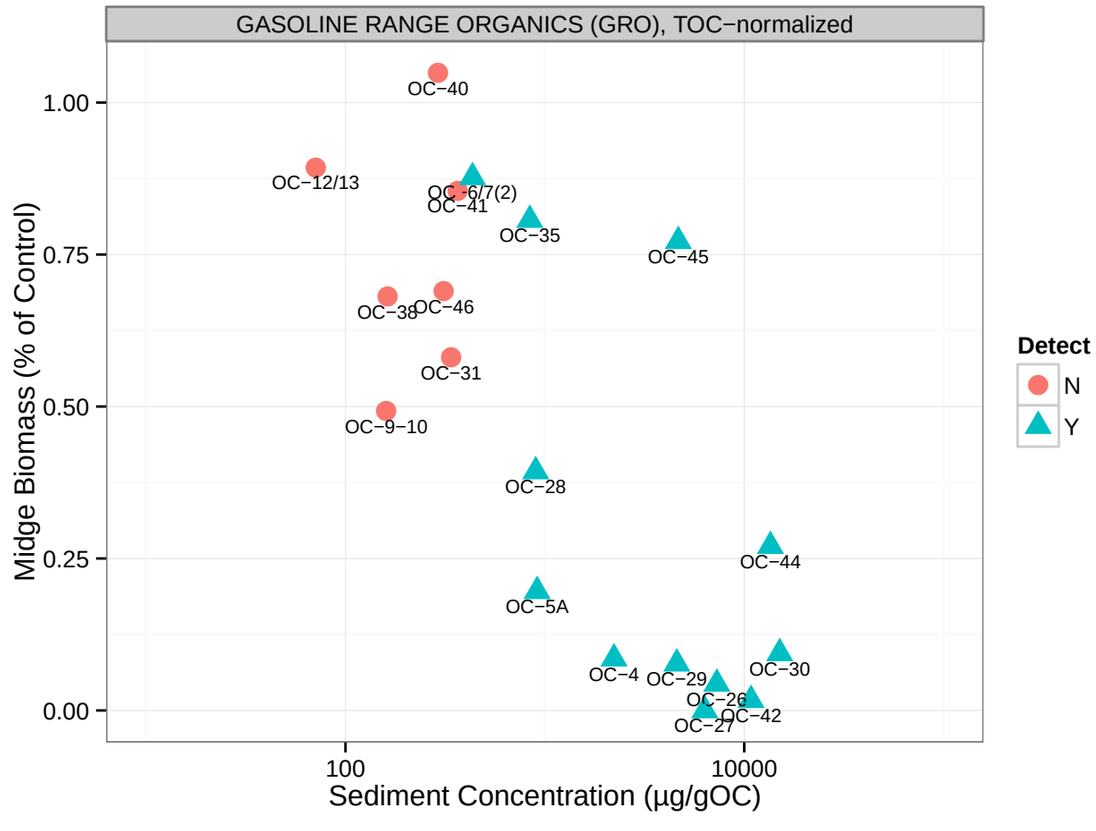

Total PAHs−34
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
100
Sediment Concentration (mg/kg)
Detect
N
Y

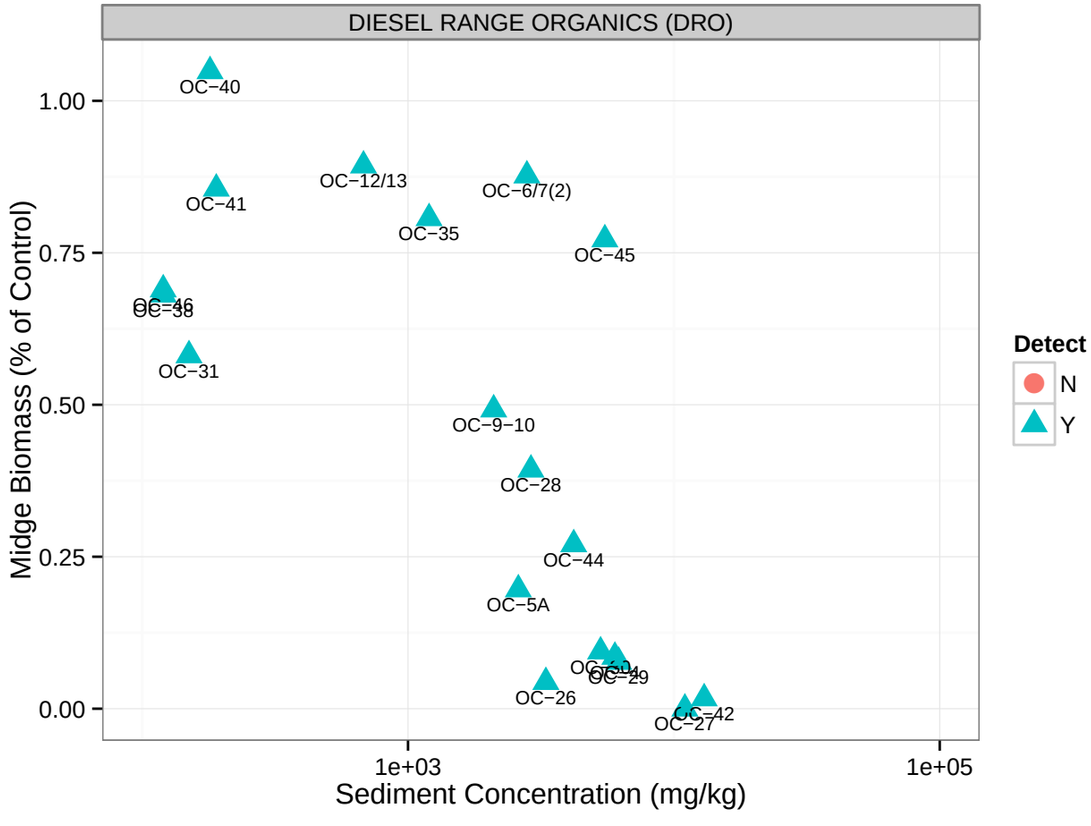

Total PAHs−34, TOC−normalized
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
100
Sediment Concentration (mg/kg at 1%TOC)
Detect
N
Y

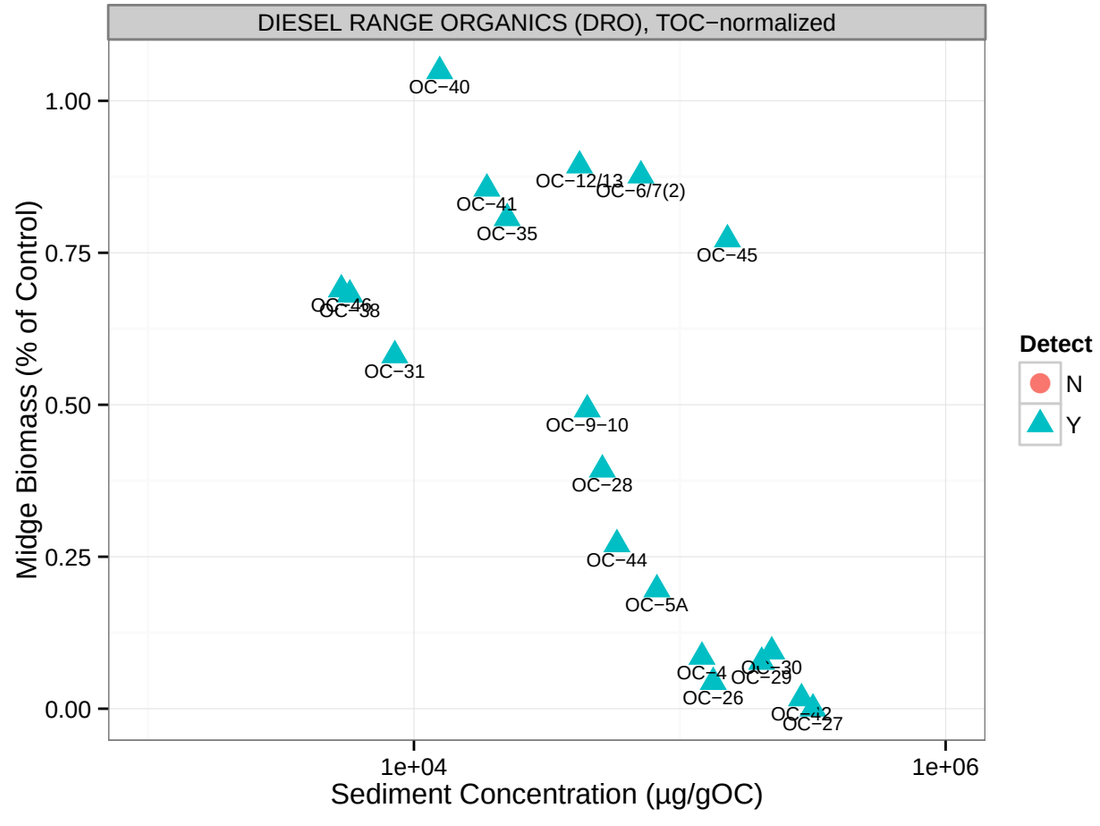

PAH ESBTU
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.1
10.0
Sediment Concentration (unitless)
OC−61
OC−40
OC−60
OC−54
OC−56
OC−53
OC−12/13
OC−6/7(2)
OC−41
OC−57
OC−35
OC−45
OC−51
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−52
OC−49
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

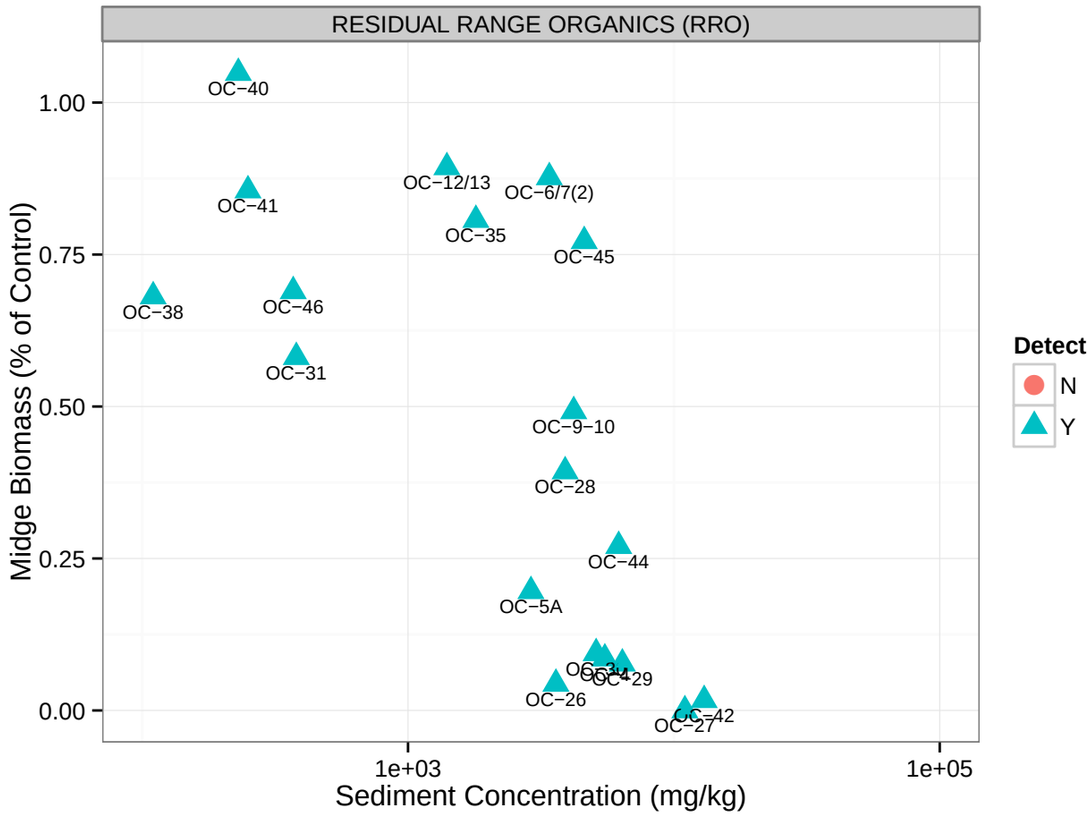

Porewater PAH TU
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
100
Porewater Concentration (unitless)
OC−40
OC−61
OC−58
OC−59
OC−55
OC−60
OC−54
OC−53
OC−12/13
OC−6/7(2)
OC−41
OC−57
OC−56
OC−35
OC−45
OC−38
OC−46
OC−51
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−4
OC−29
OC−52
OC−49
OC−50
OC−26
OC−27
OC−42
Detect
N
Y

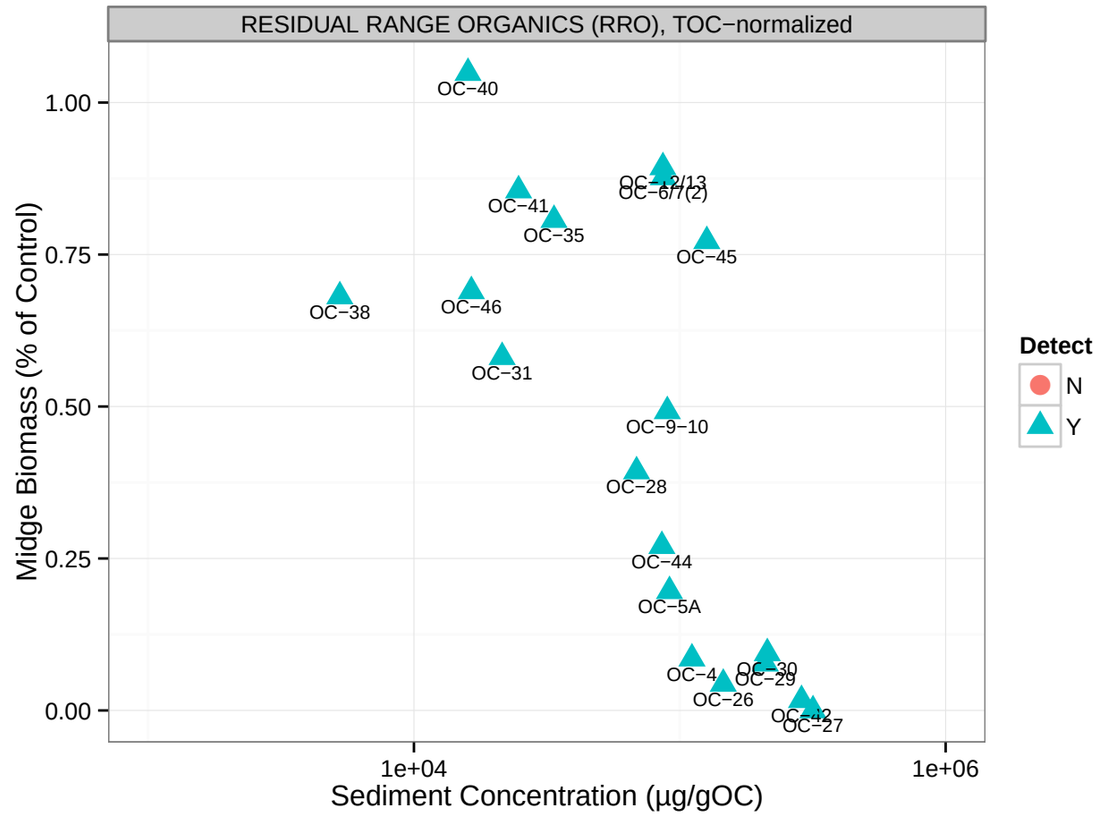

GASOLINE RANGE ORGANICS (GRO)
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
1000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−41
OC−6/7(2)
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−26
OC−27
OC−42
Detect
N
Y


GASOLINE RANGE ORGANICS (GRO), TOC−normalized
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
100
10000
Sediment Concentration (µg/gOC)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−26
OC−27
OC−42
Detect
N
Y

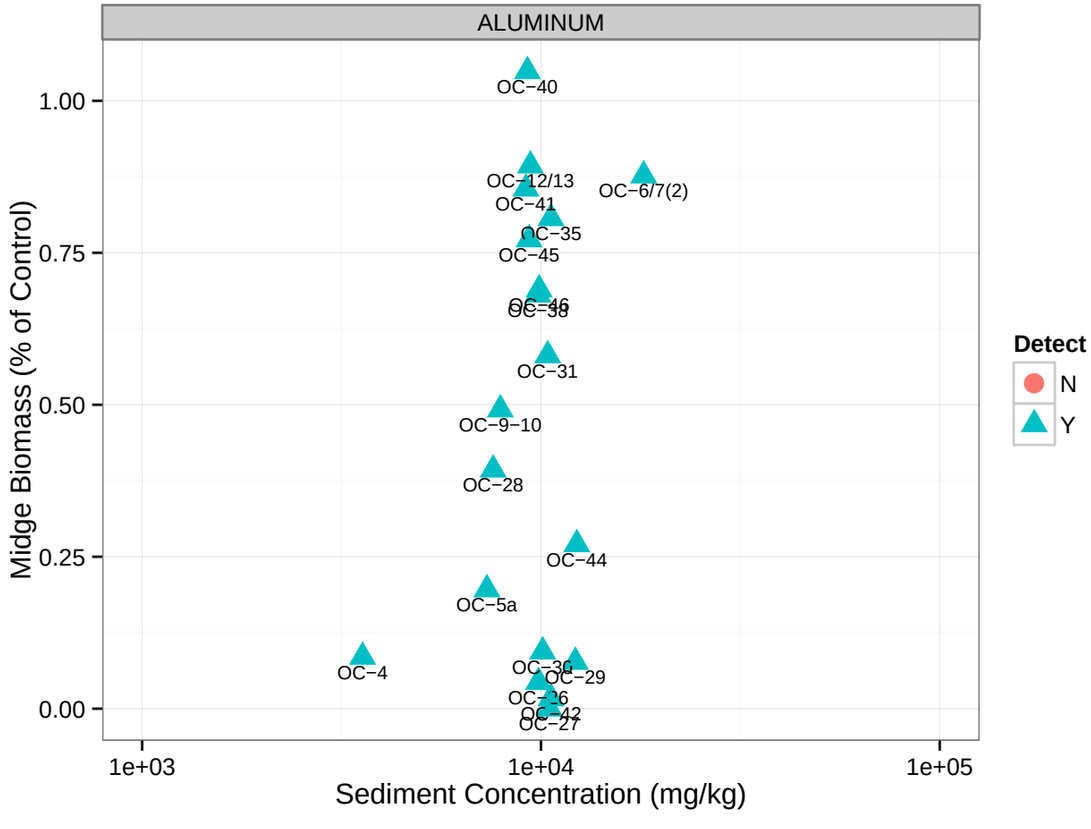

DIESEL RANGE ORGANICS (DRO)
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−41
OC−12/13
OC−6/7(2)
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−26
OC−42
OC−27
1e+03
1e+05
Sediment Concentration (mg/kg)
Detect
N
Y

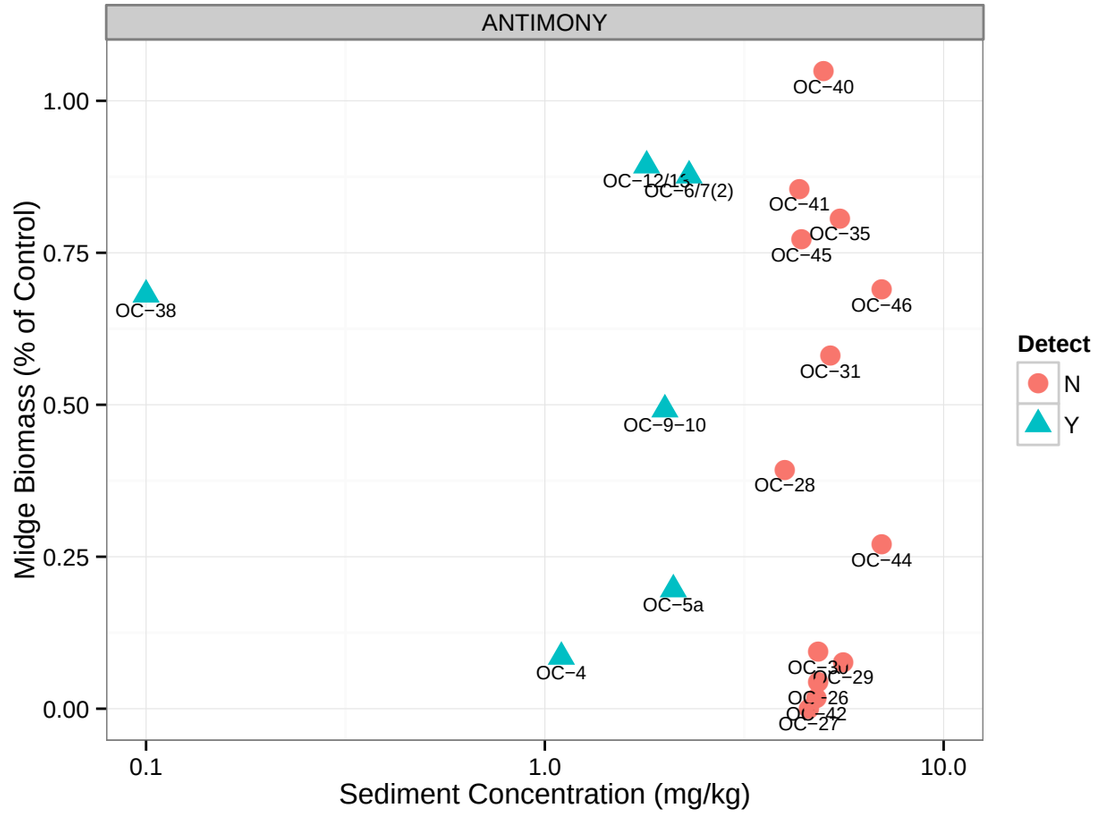

DIESEL RANGE ORGANICS (DRO), TOC−normalized
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
1e+04
1e+06
Sediment Concentration (µg/gOC)
Detect
N
Y

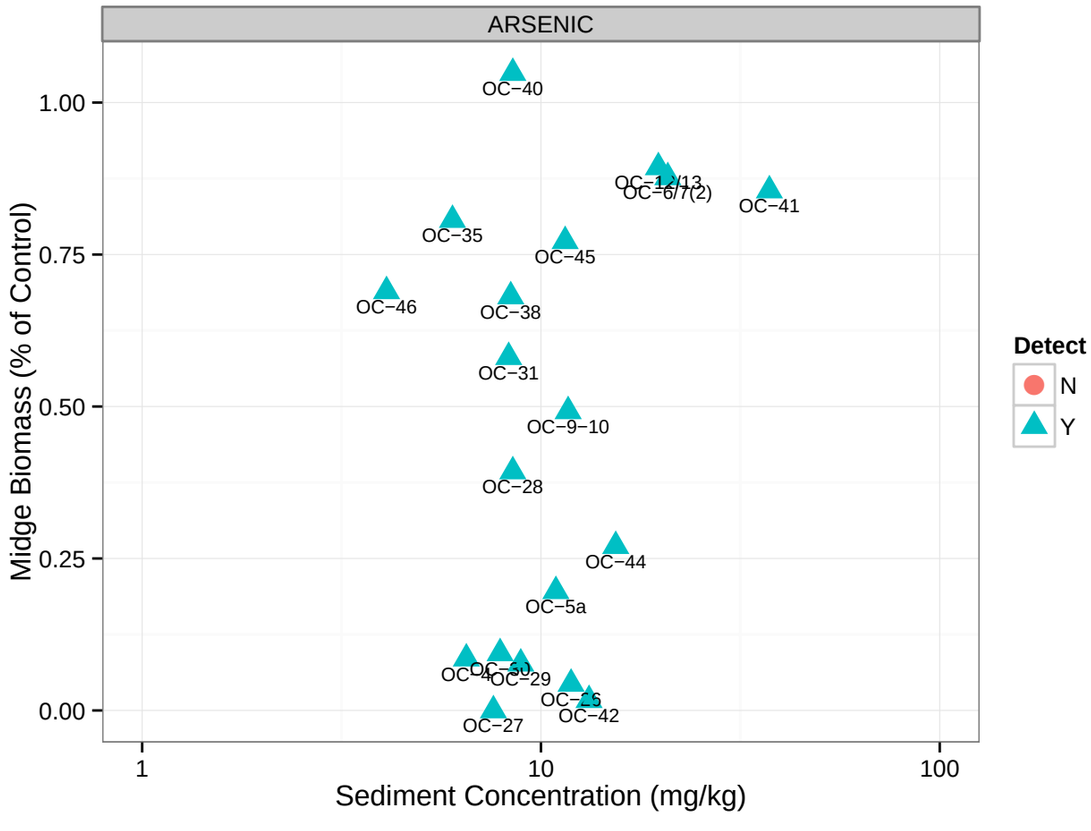

RESIDUAL RANGE ORGANICS (RRO)
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−41
OC−12/13
OC−6/7(2)
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−26
OC−42
OC−27
1e+03
1e+05
Sediment Concentration (mg/kg)
Detect
N
Y

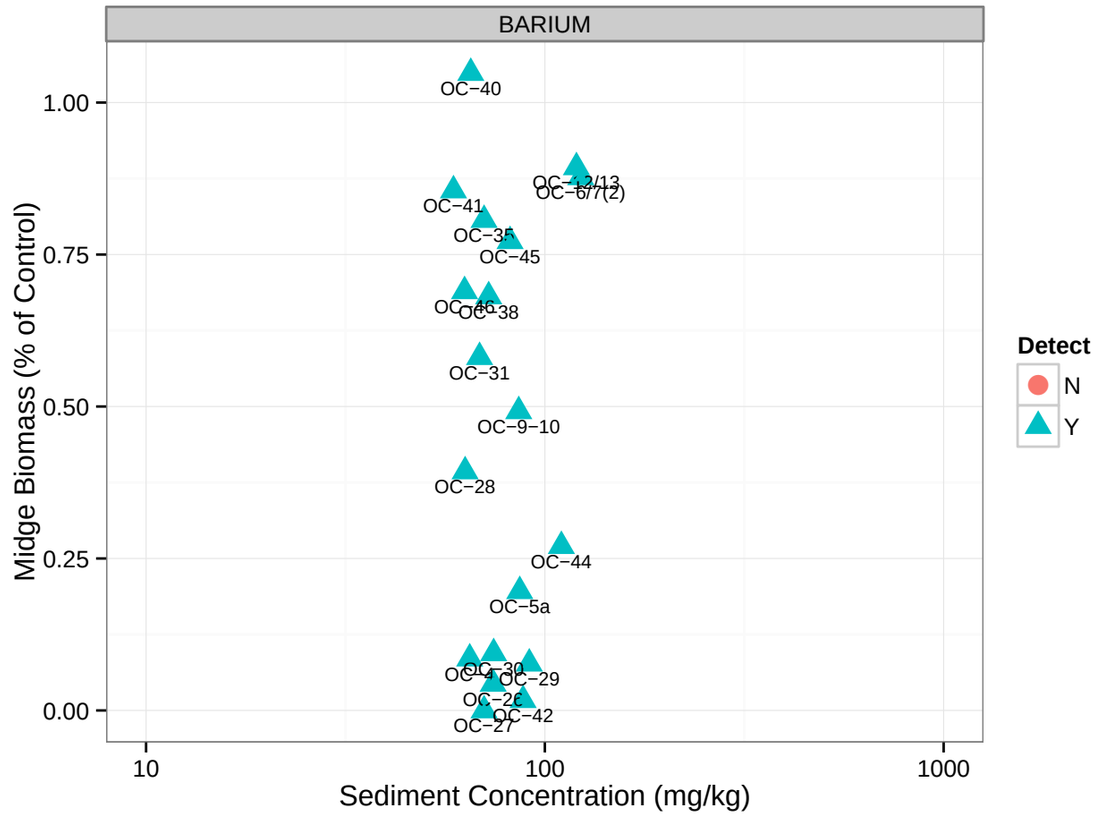

RESIDUAL RANGE ORGANICS (RRO), TOC−normalized
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−26
OC−27
1e+04
1e+06
Sediment Concentration (µg/gOC)
Detect
N
Y

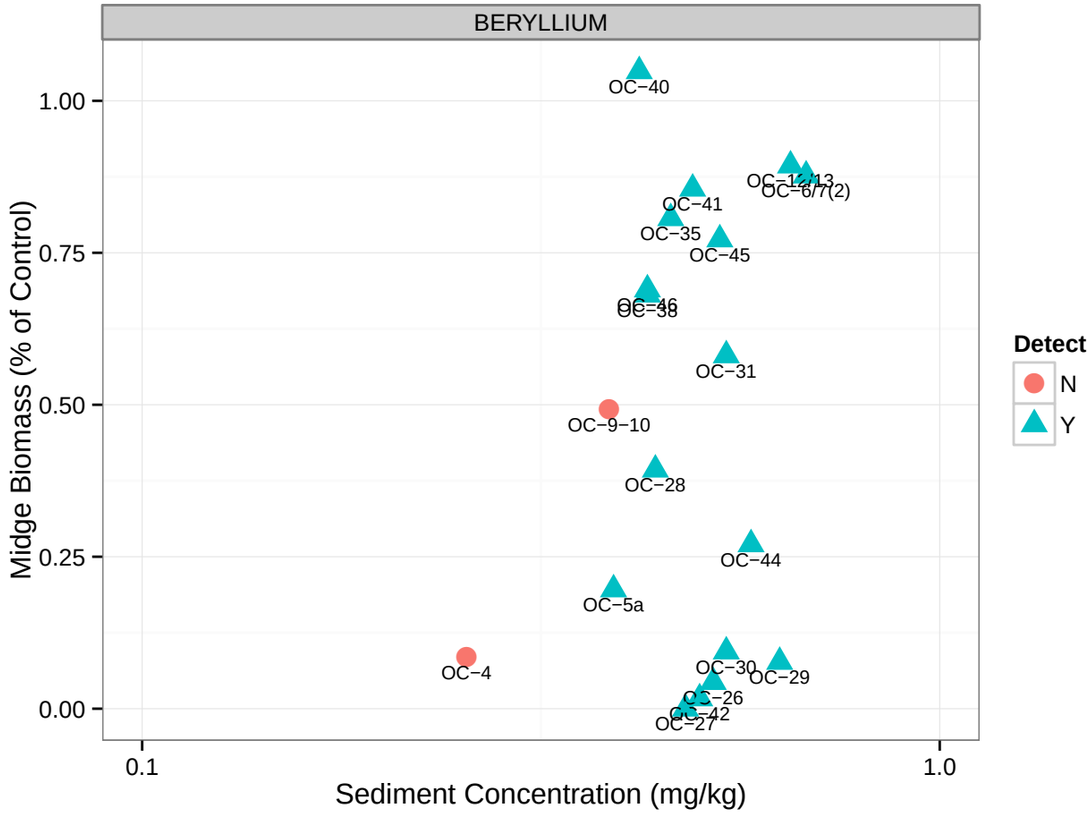
Attachment 2b: Analtyical Parameters versus Midge Biomass, Lower Otter Creek Only

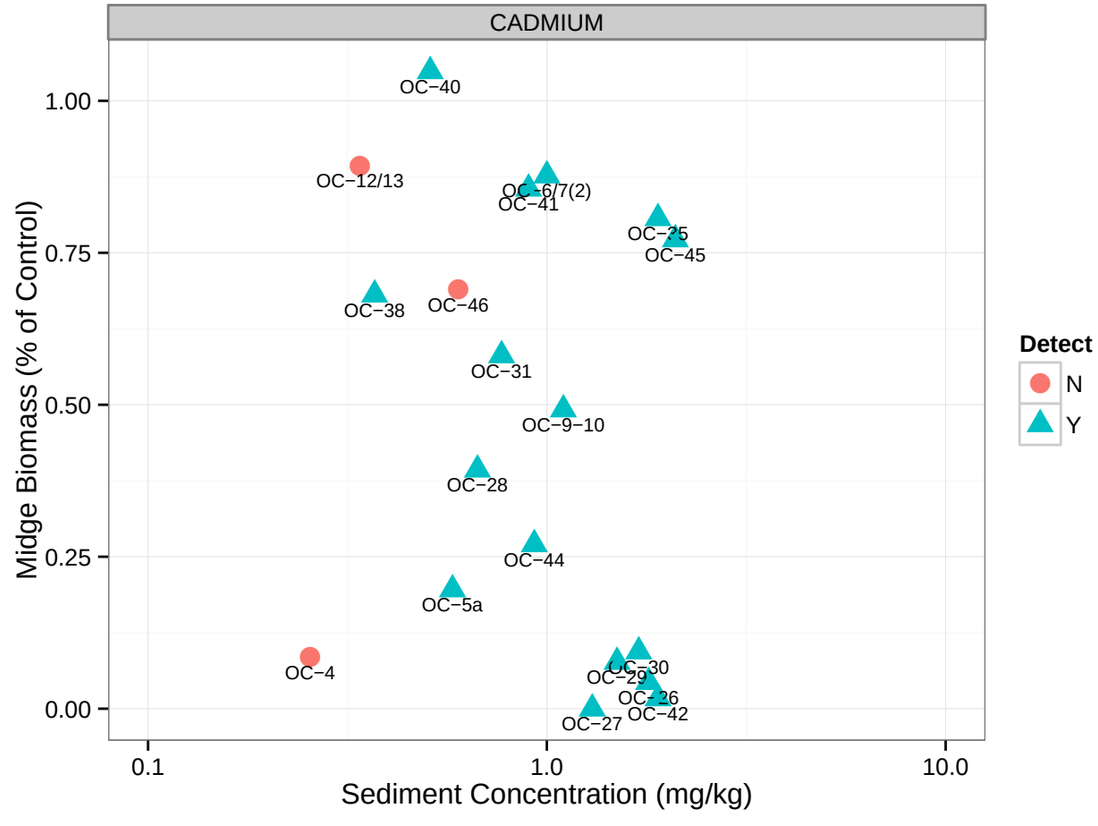


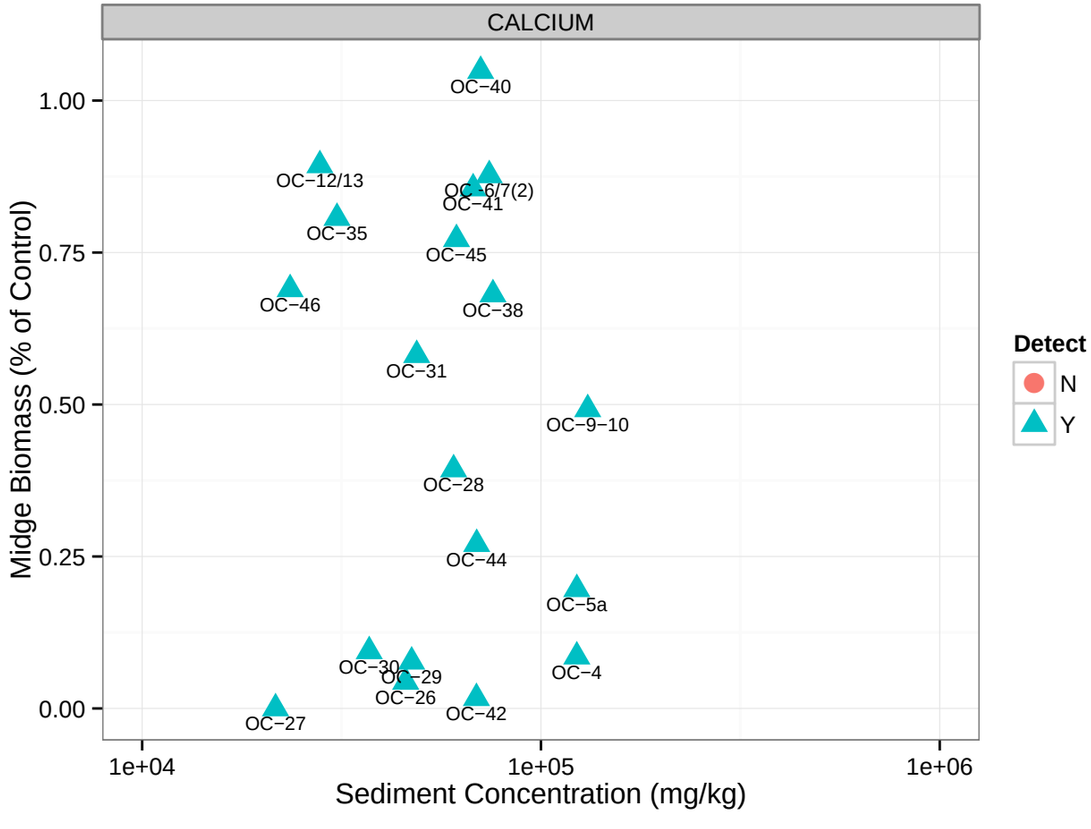


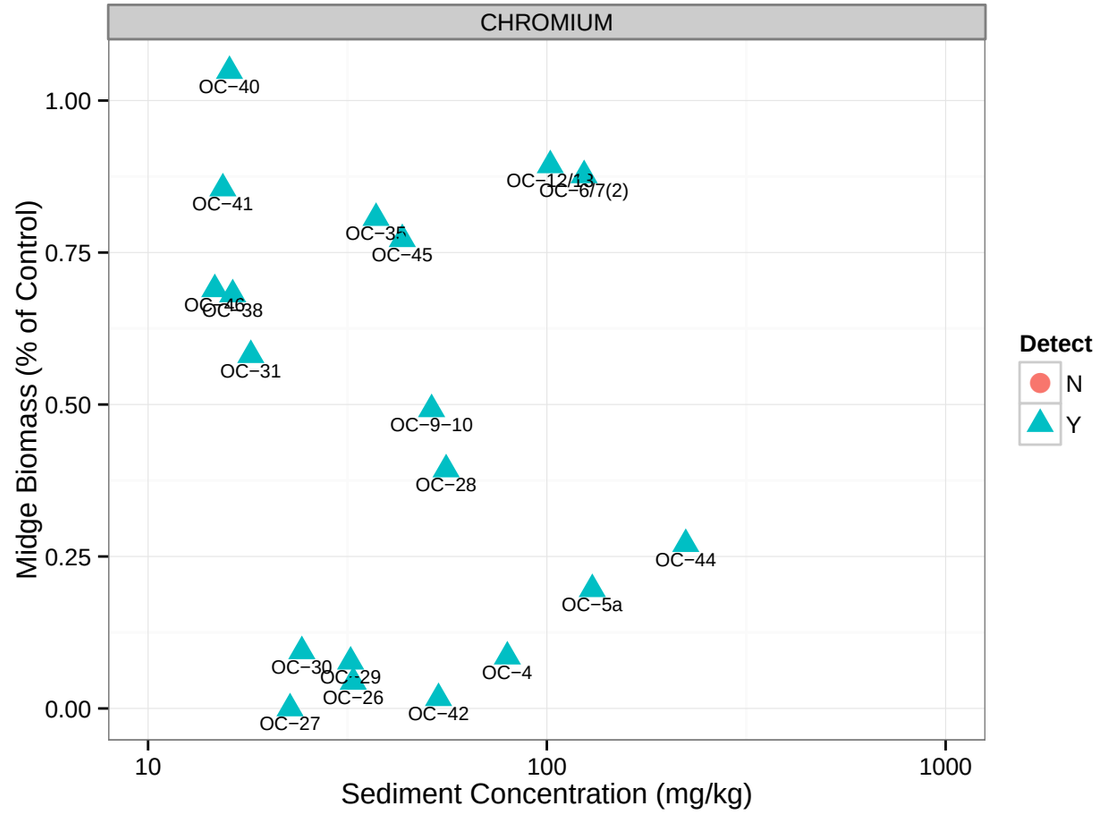


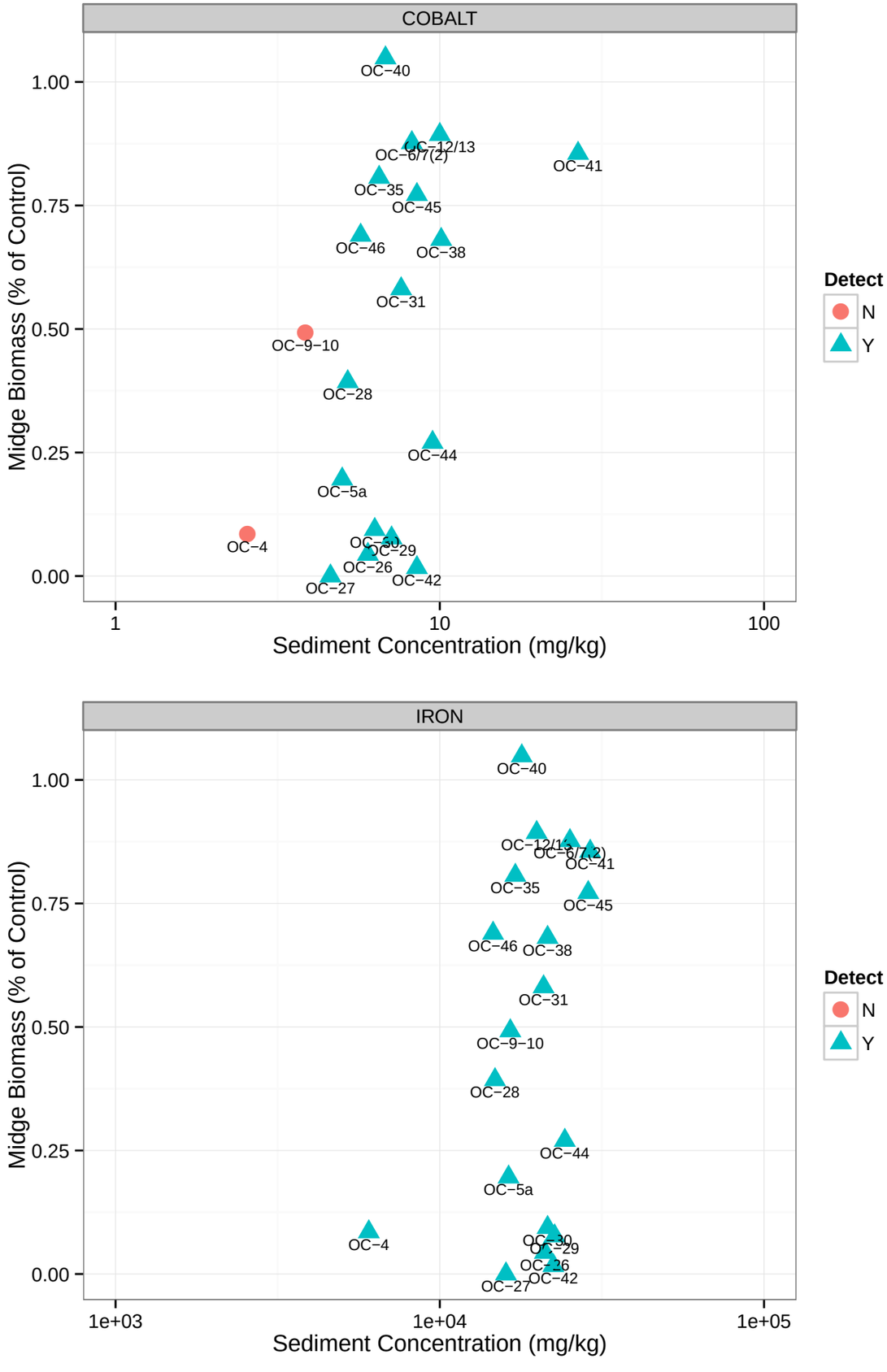


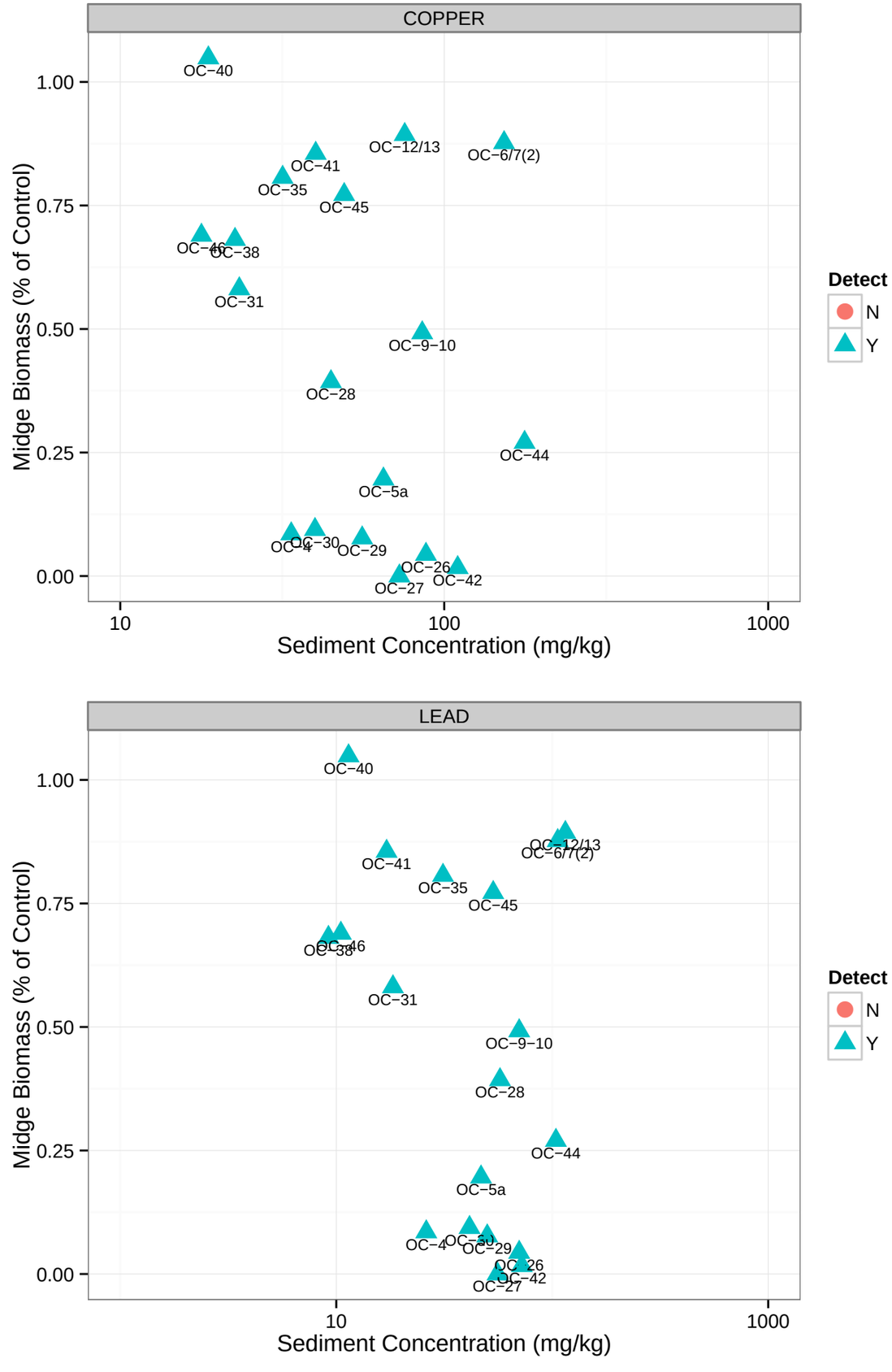

BERYLLIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.1
1.0
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y


CADMIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.1
1.0
10.0
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−27
OC−42
Detect
N
Y


CALCIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e+04
1e+05
1e+06
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y


CHROMIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
100
1000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

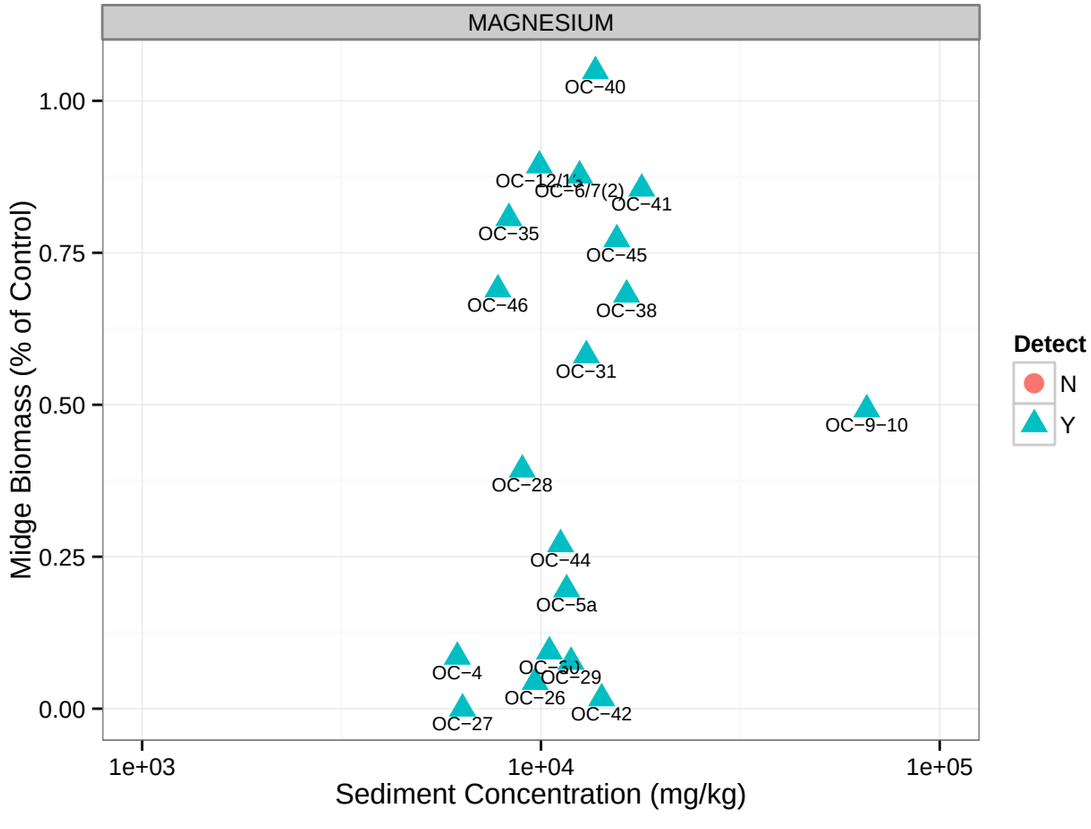

COBALT
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
10
100
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

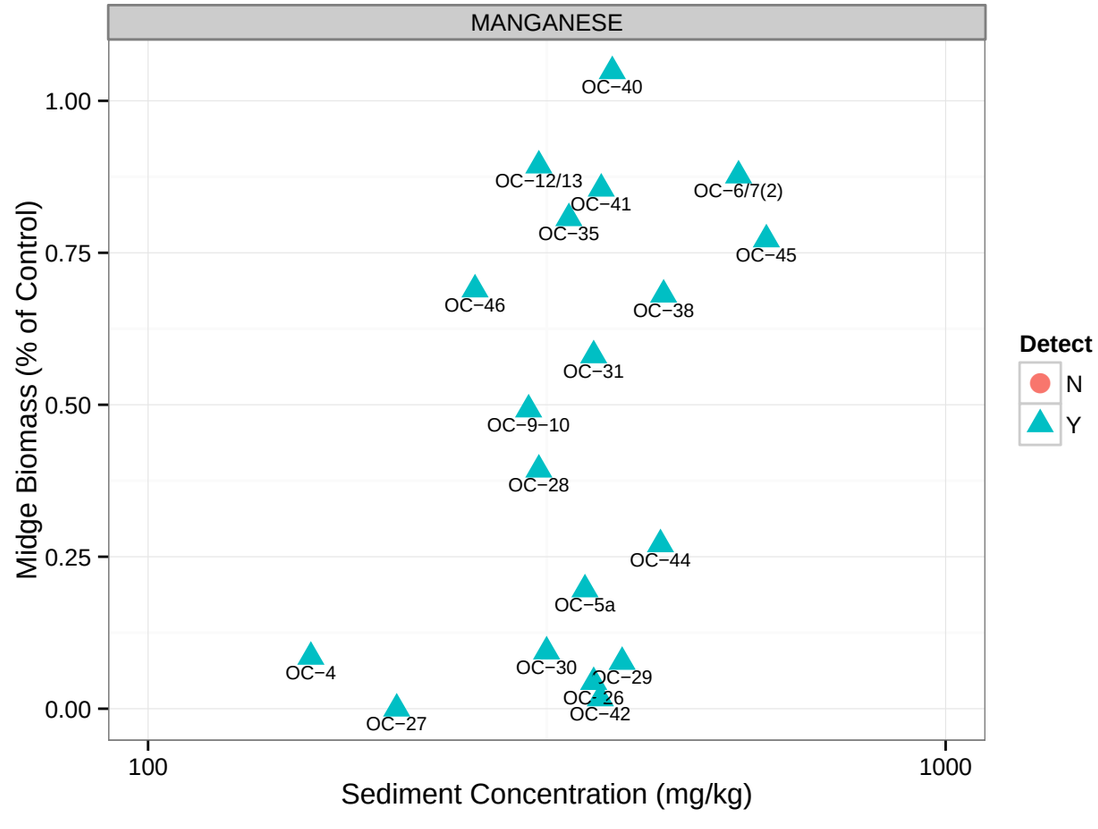

COPPER
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
100
1000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

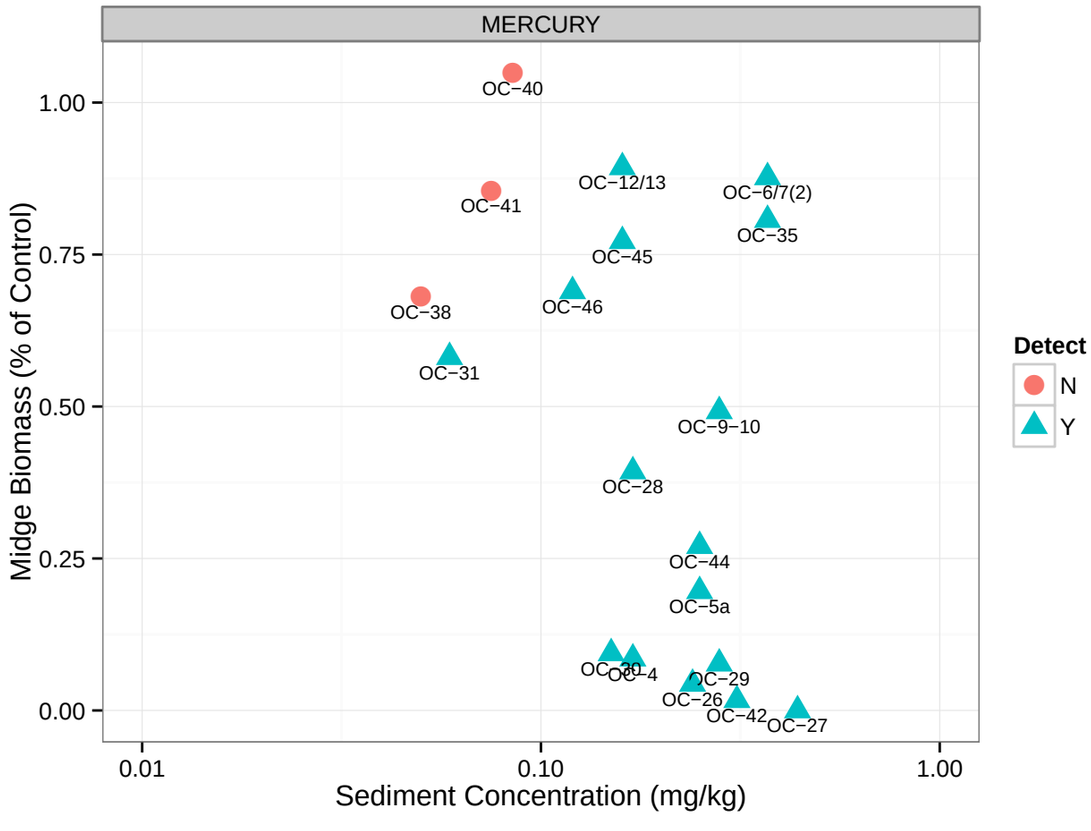
IRON
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e+03
1e+04
1e+05
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

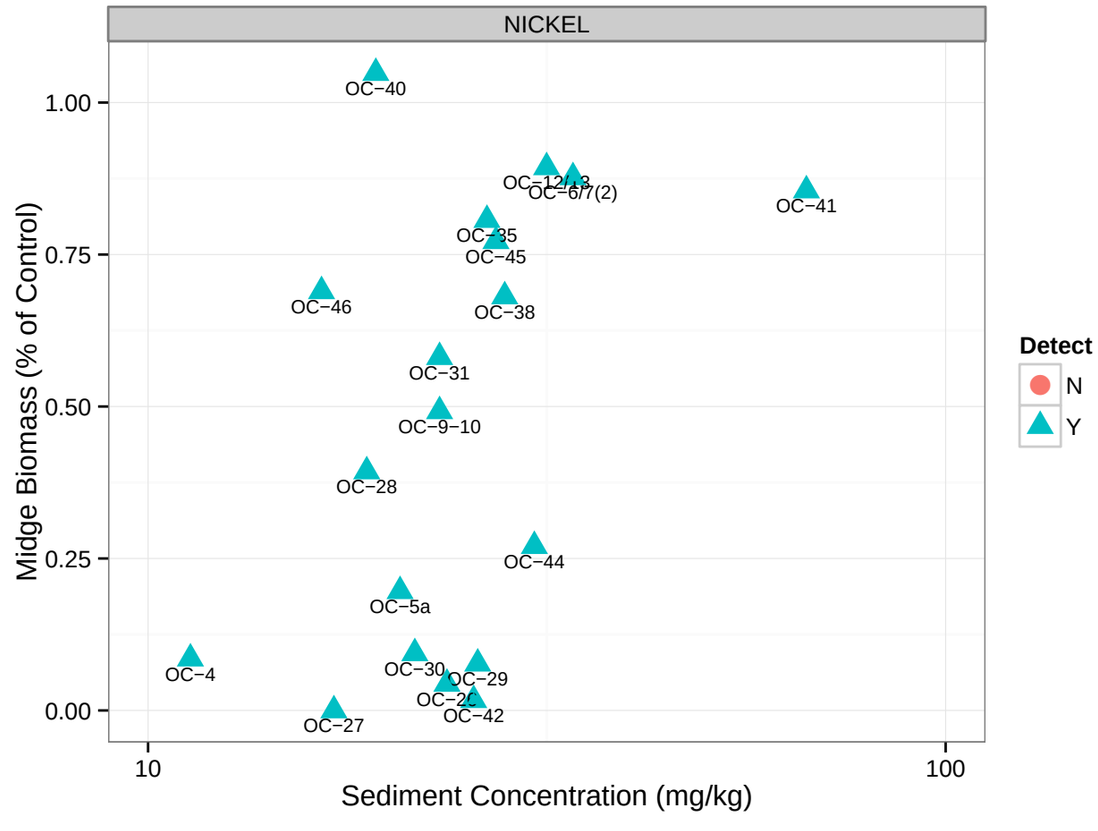
LEAD
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
1000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

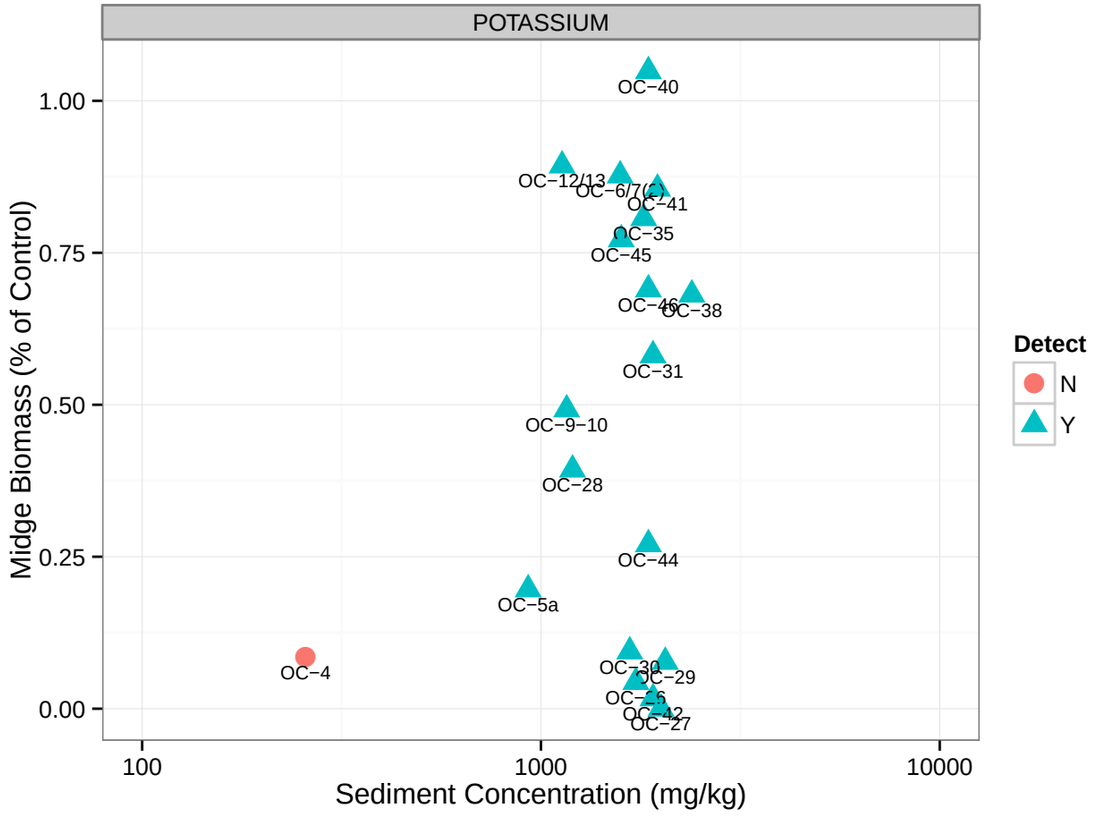
Attachment 2b: Analtyical Parameters versus Midge Biomass, Lower Otter Creek Only

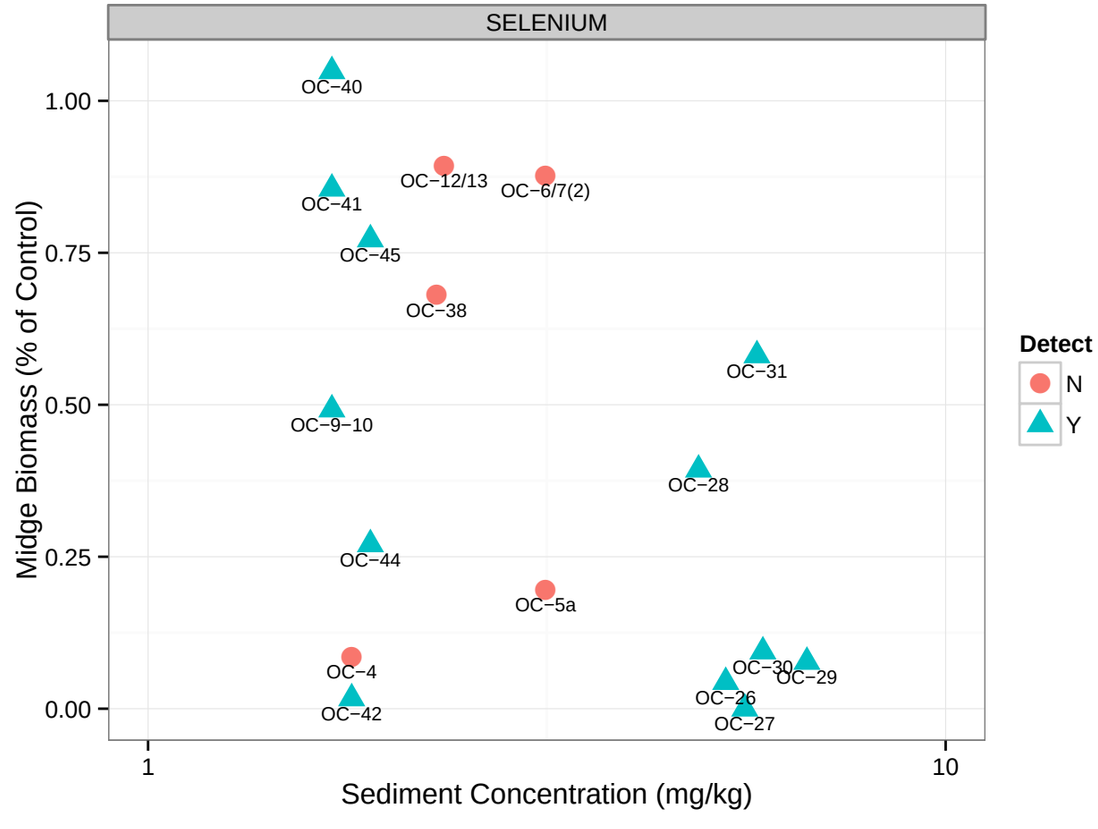


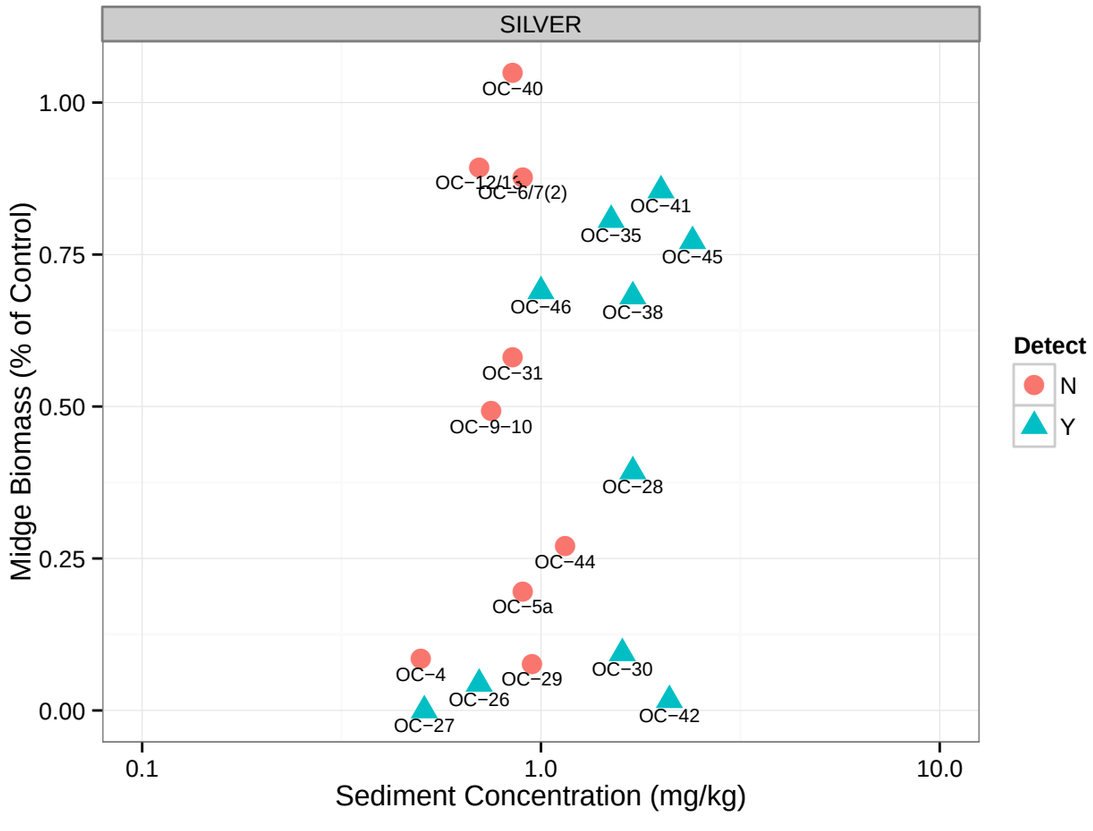


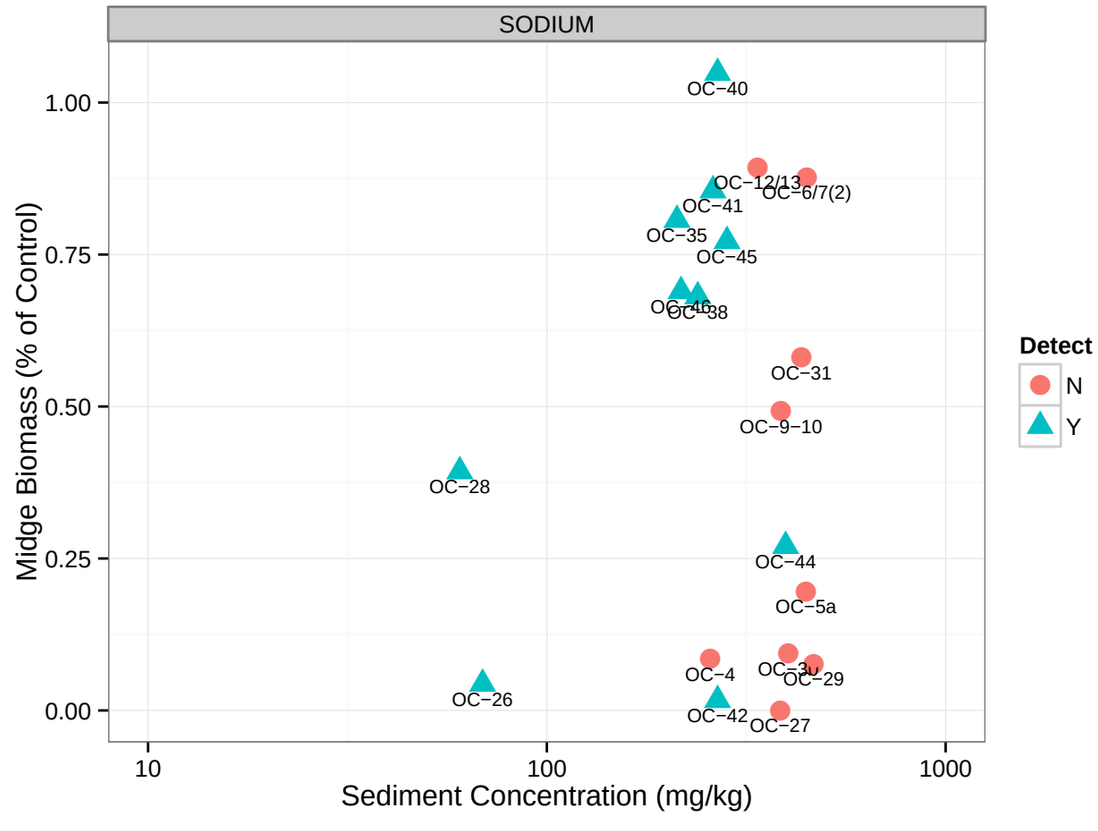


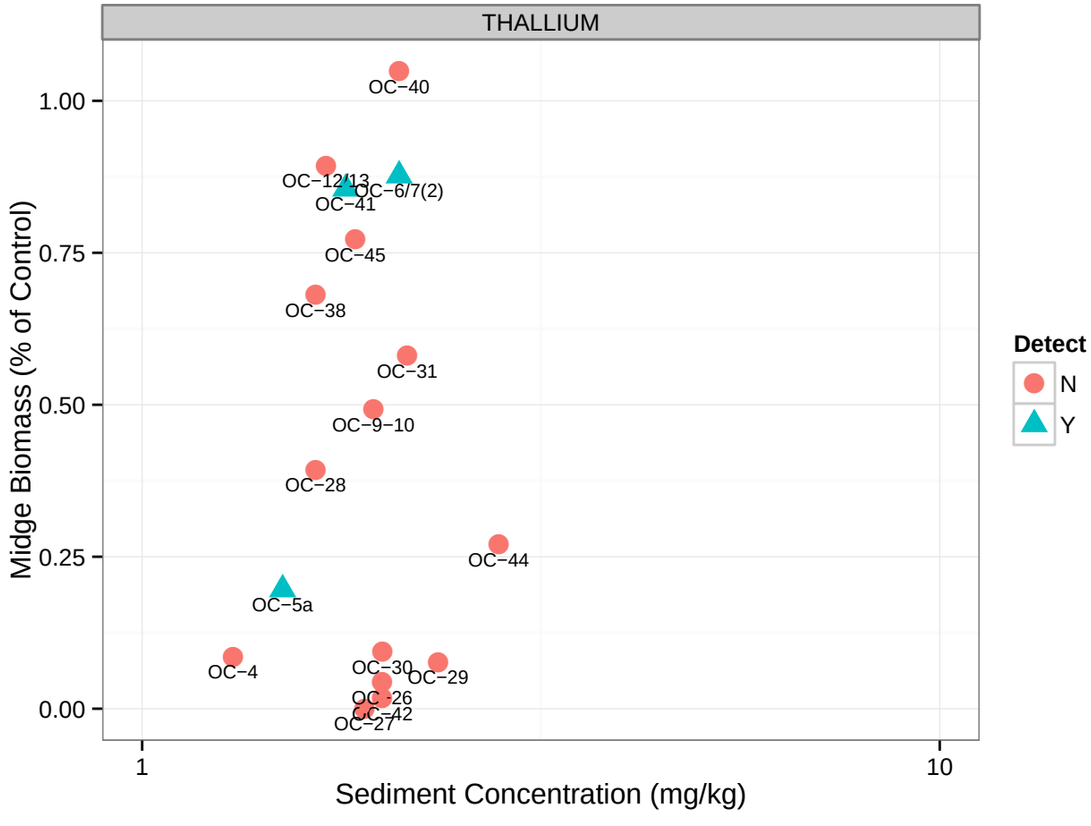


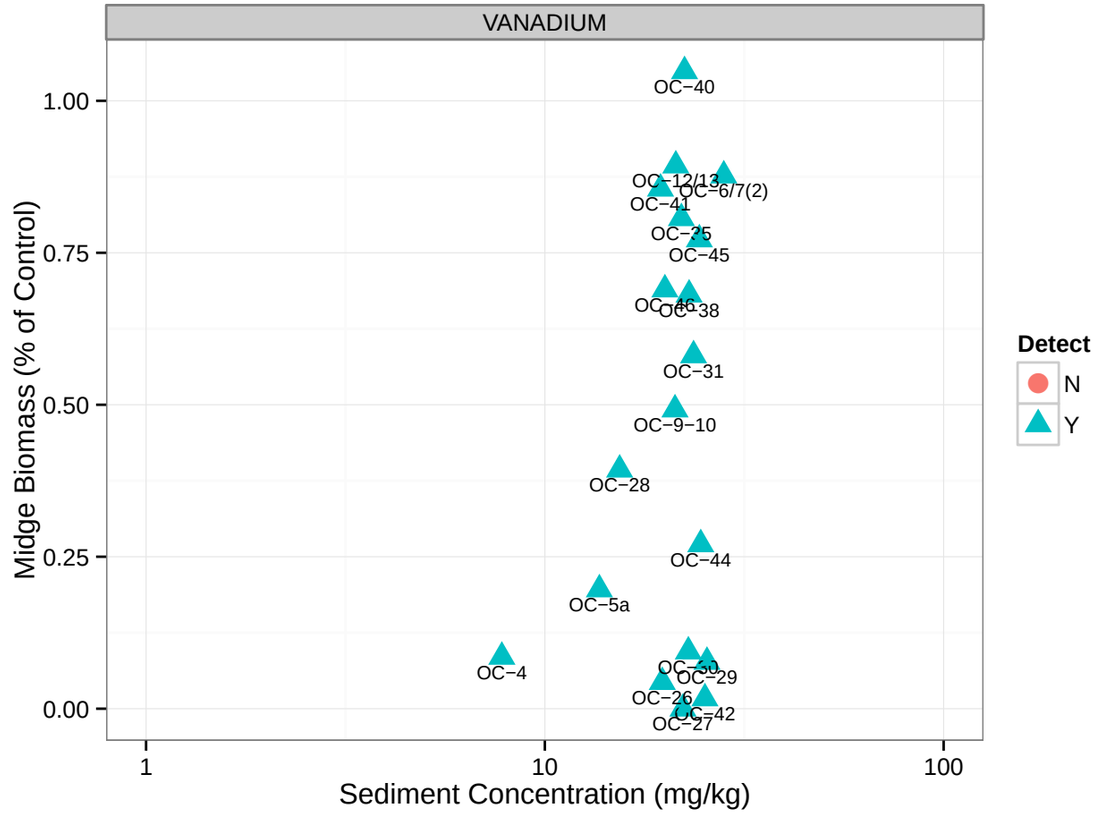

POTASSIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
100
1000
10000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

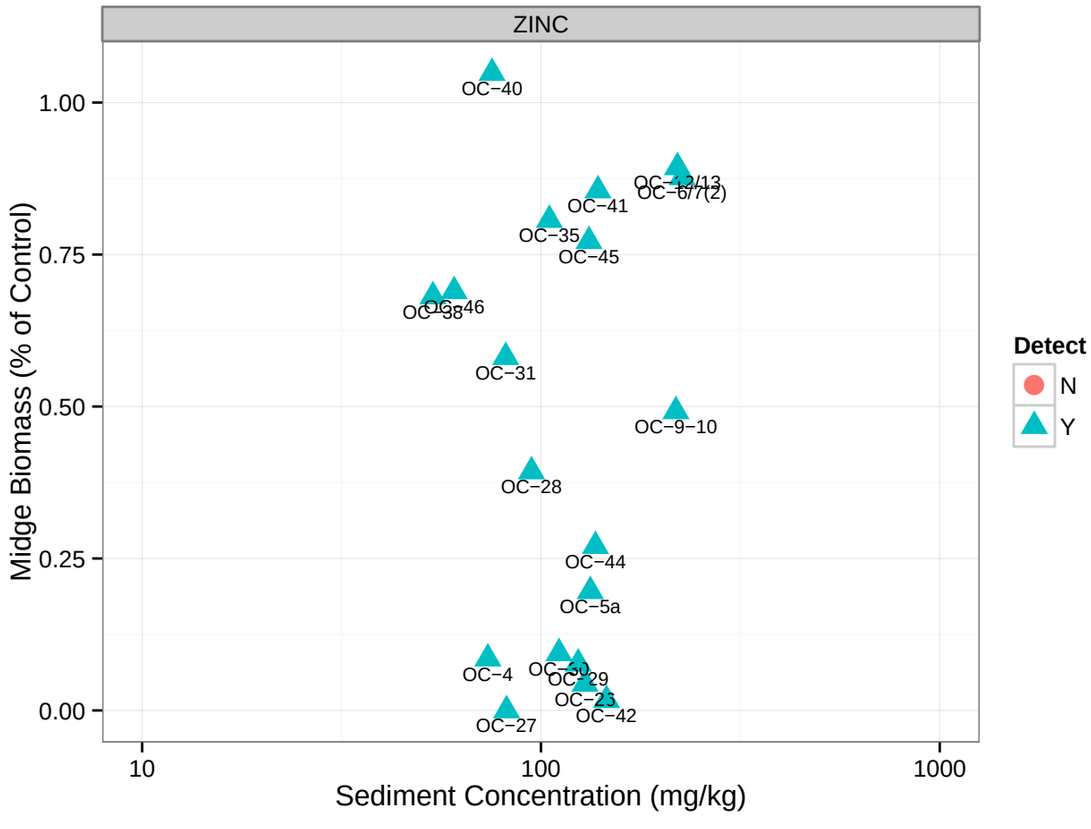

SELENIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
10
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−45
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−42
OC−30
OC−29
OC−26
OC−27
Detect
N
Y

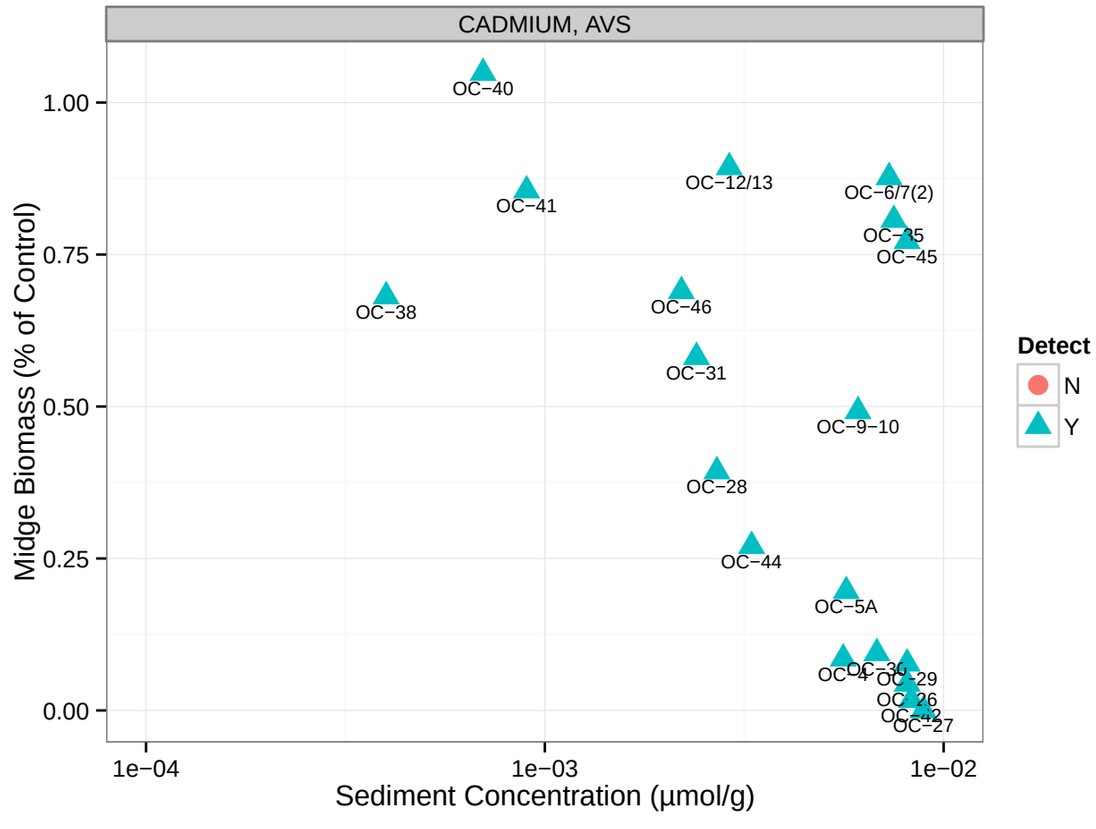

SILVER
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.1
1.0
10.0
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−26
OC−27
OC−30
OC−42
Detect
N
Y

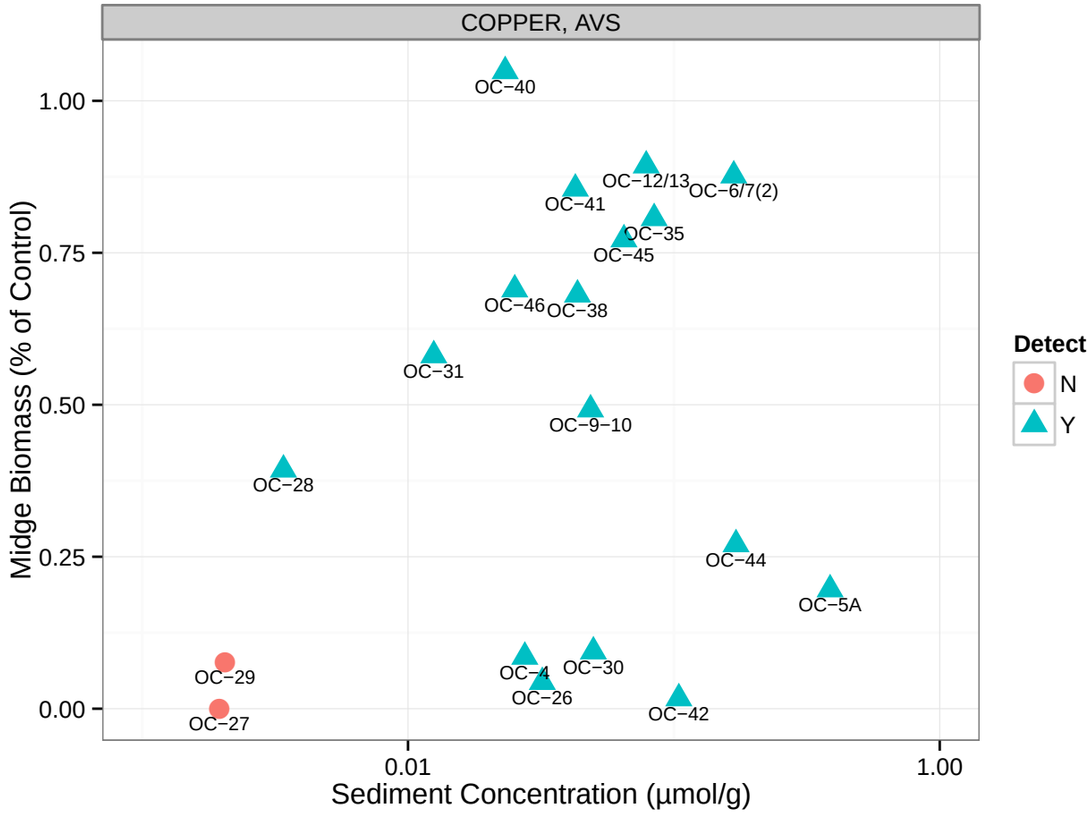

SODIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
100
1000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

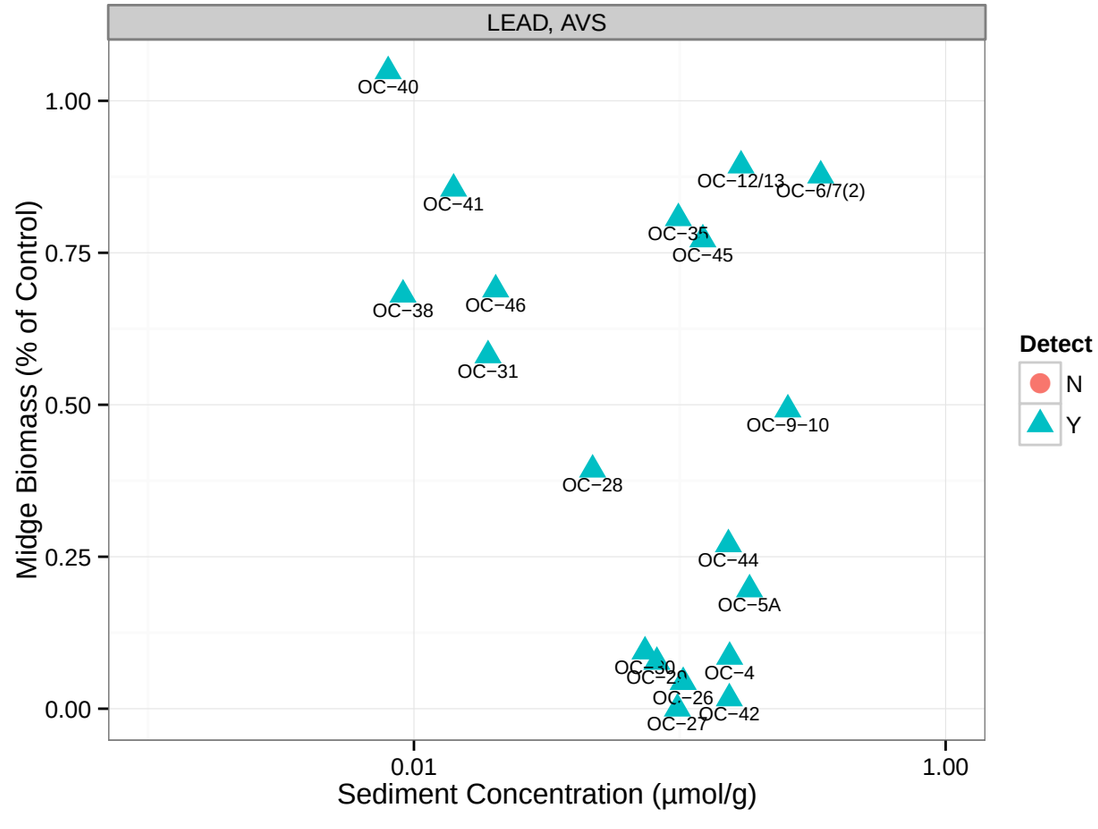

THALLIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
10
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−45
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

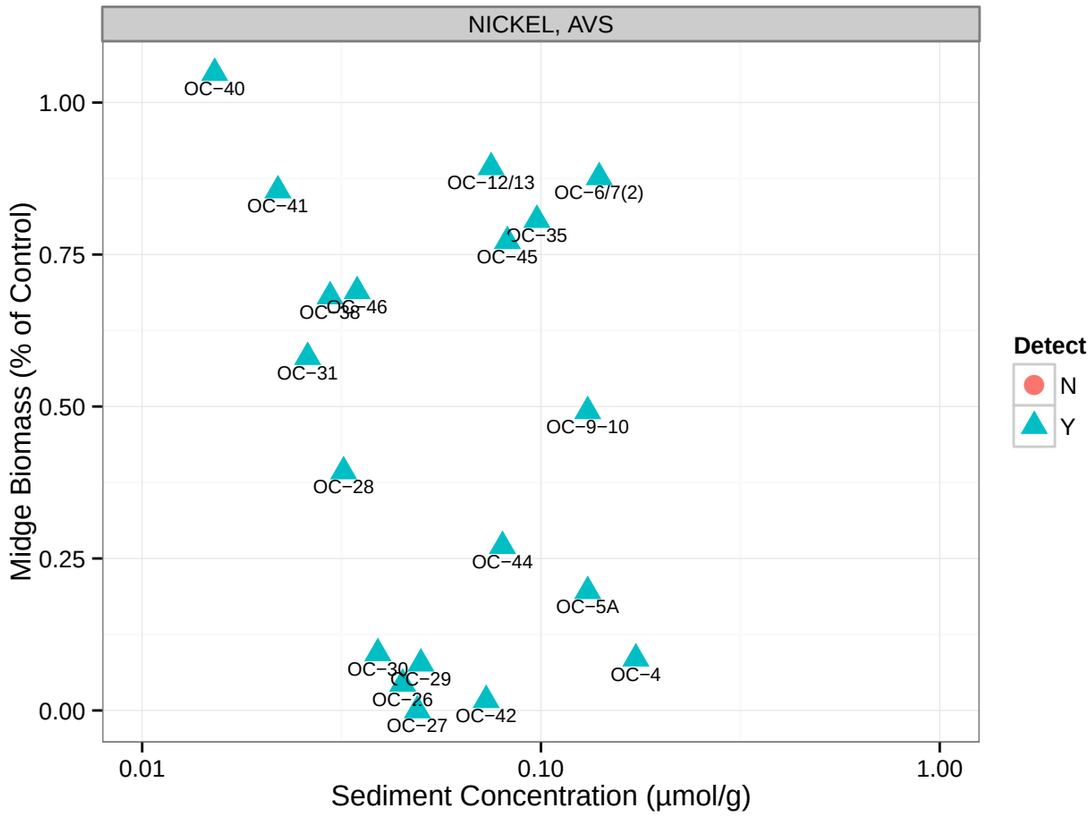

VANADIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
10
100
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

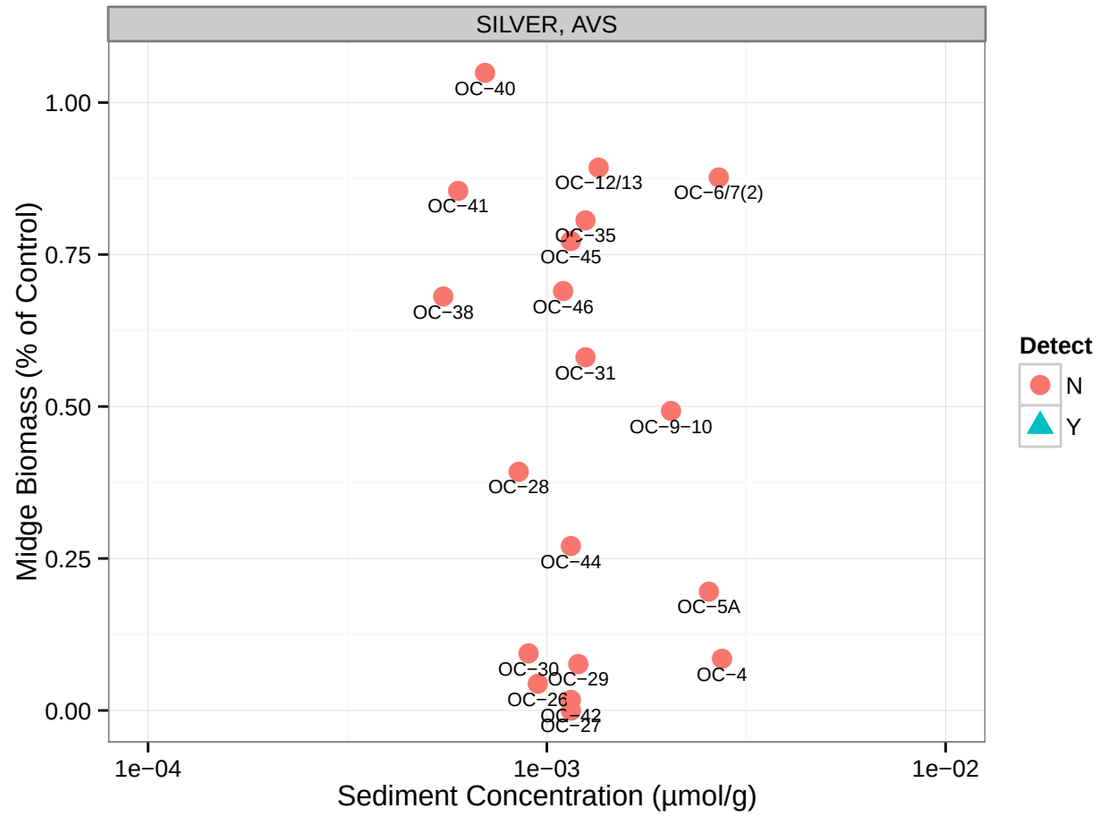

ZINC
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
100
1000
Sediment Concentration (mg/kg)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5a
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y


CADMIUM, AVS
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e−04
1e−03
1e−02
Sediment Concentration (µmol/g)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

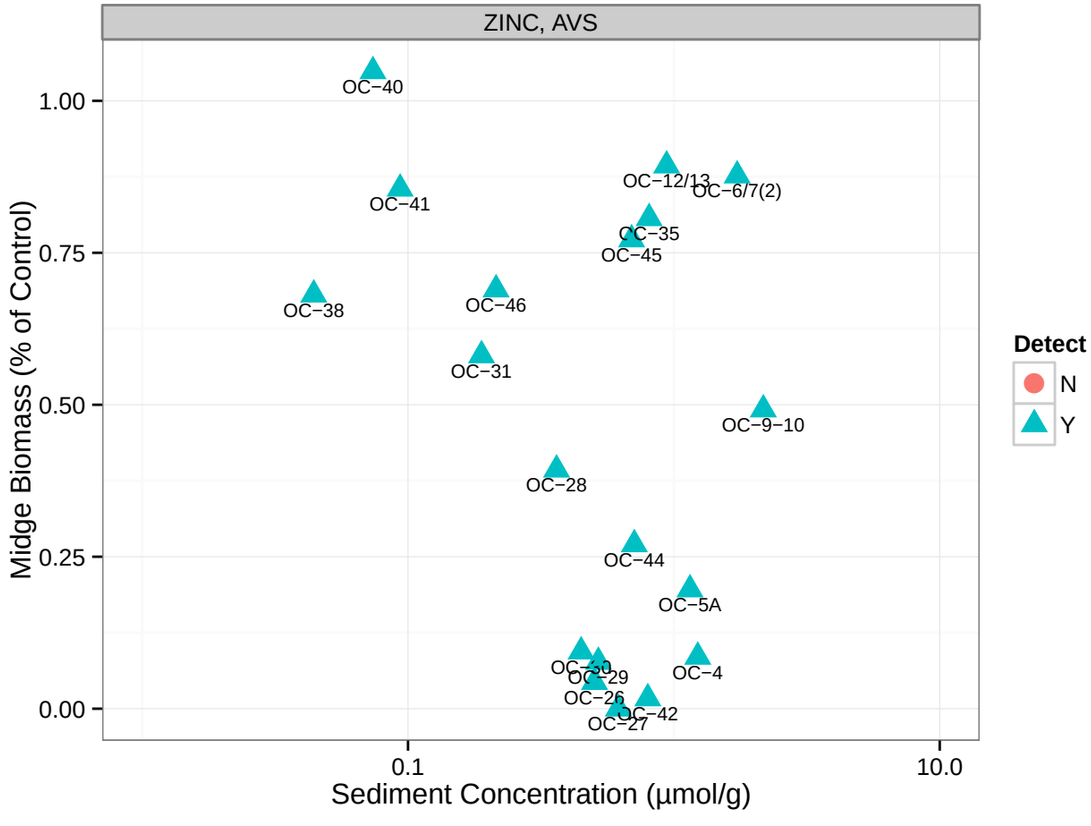

COPPER, AVS
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.01
1.00
Sediment Concentration (µmol/g)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−4
OC−30
OC−26
OC−42
OC−27
Detect
N
Y

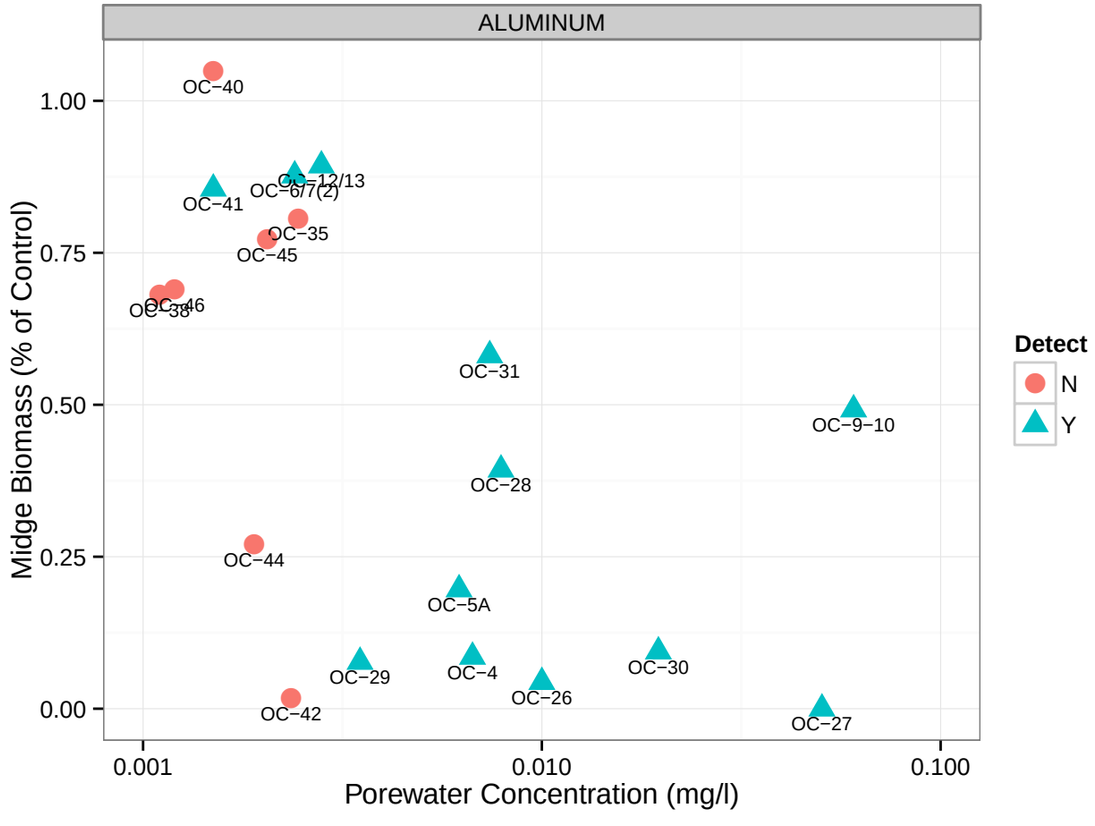

LEAD, AVS
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.01
1.00
Sediment Concentration (µmol/g)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

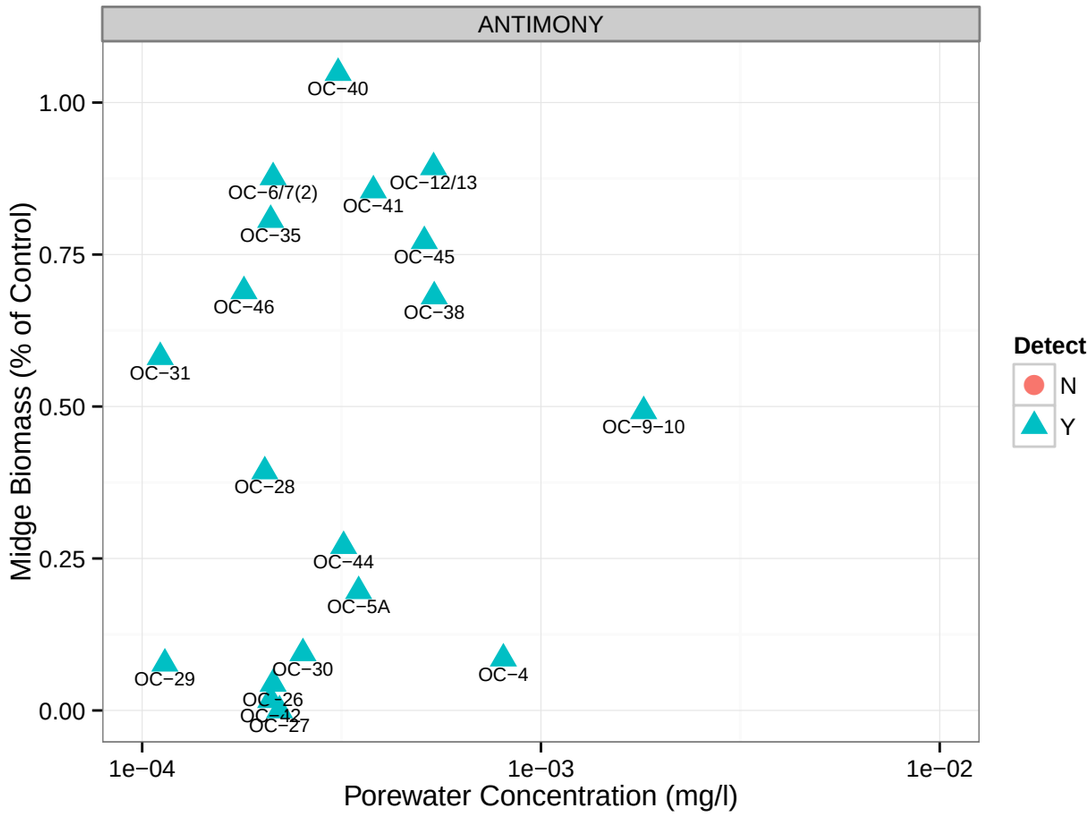

NICKEL, AVS
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.01
0.10
1.00
Sediment Concentration (µmol/g)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

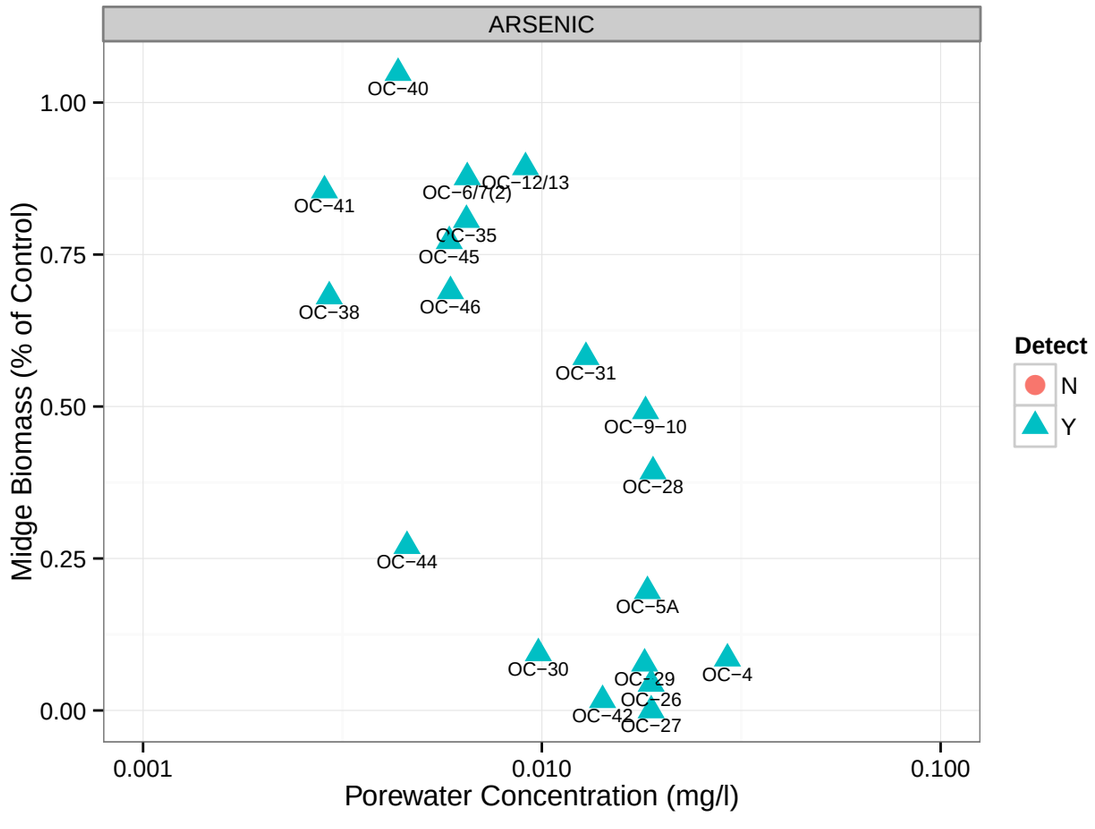

SILVER, AVS
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e−04
1e−03
1e−02
Sediment Concentration (µmol/g)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y

Attachment 2b: Analtyical Parameters versus Midge Biomass, Lower Otter Creek Only

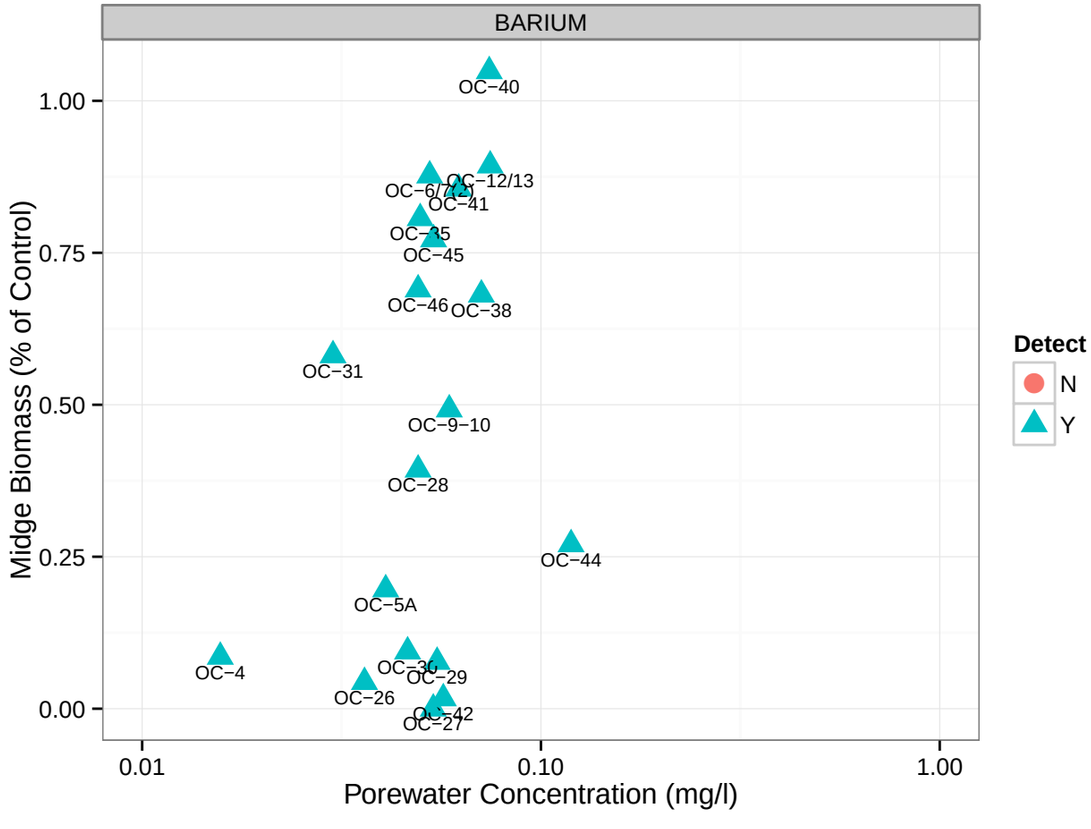


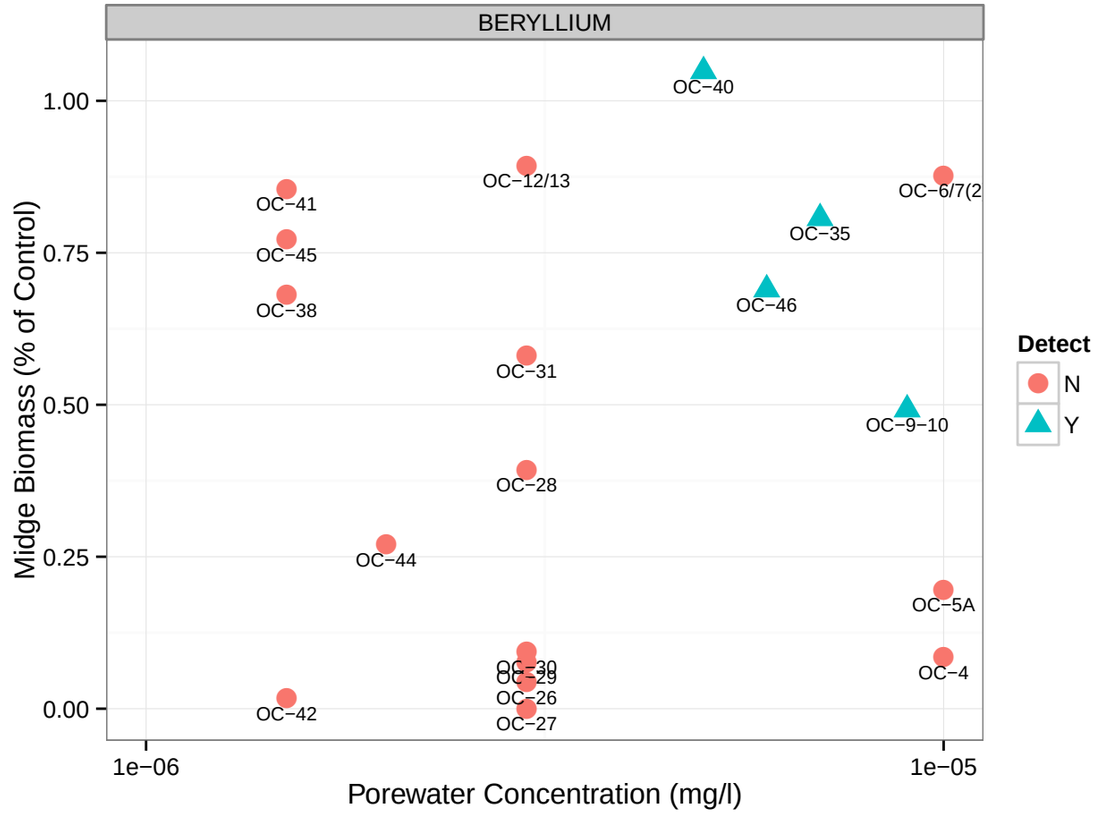


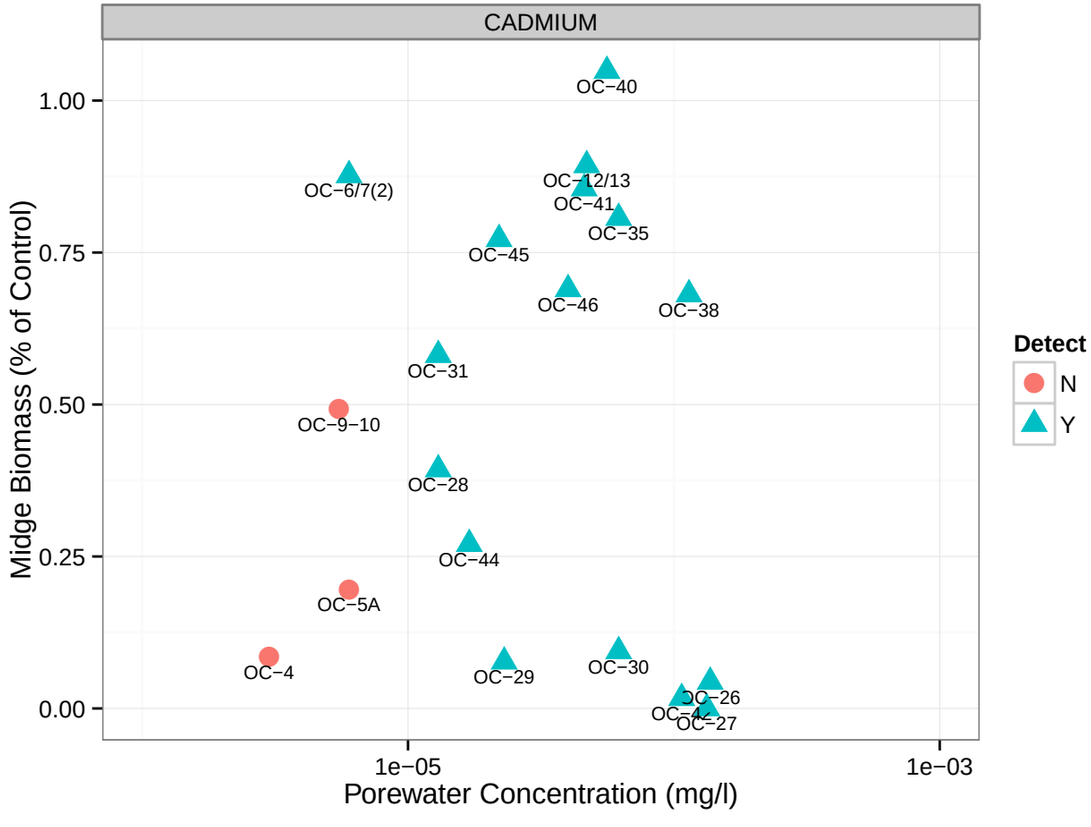


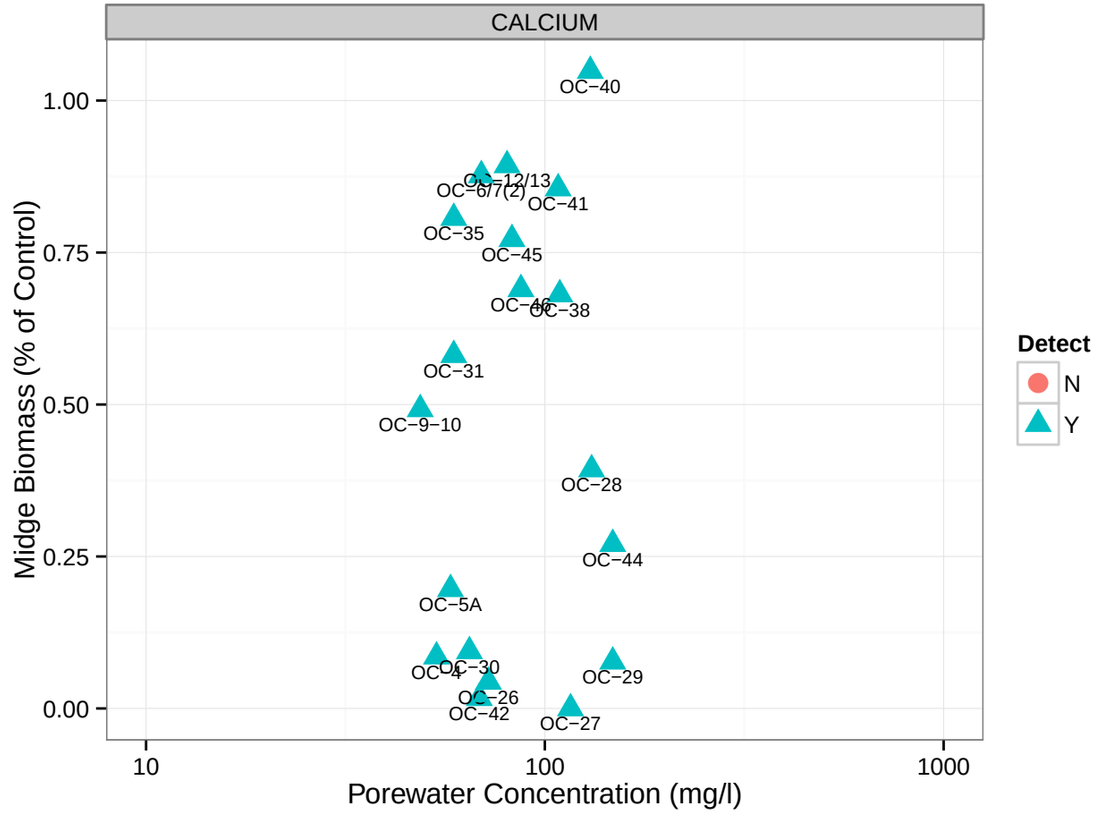


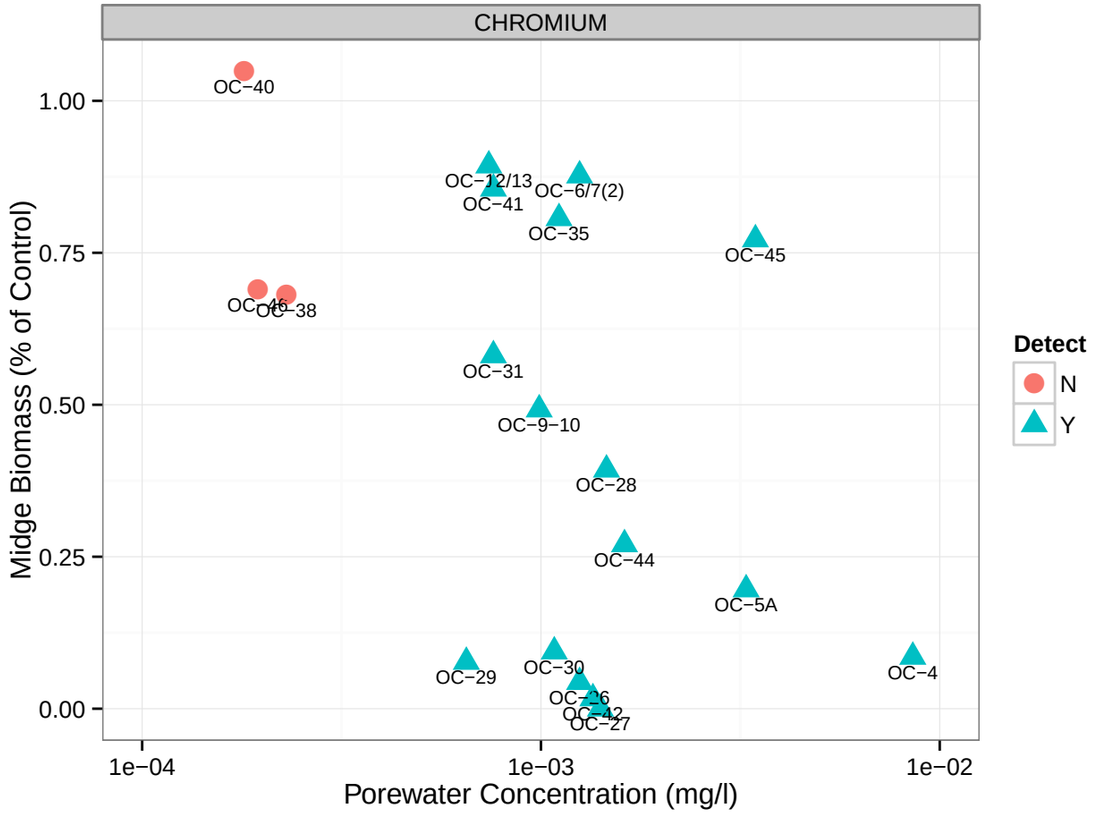
Attachment 2b: Analtyical Parameters versus Midge Biomass, Lower Otter Creek Only

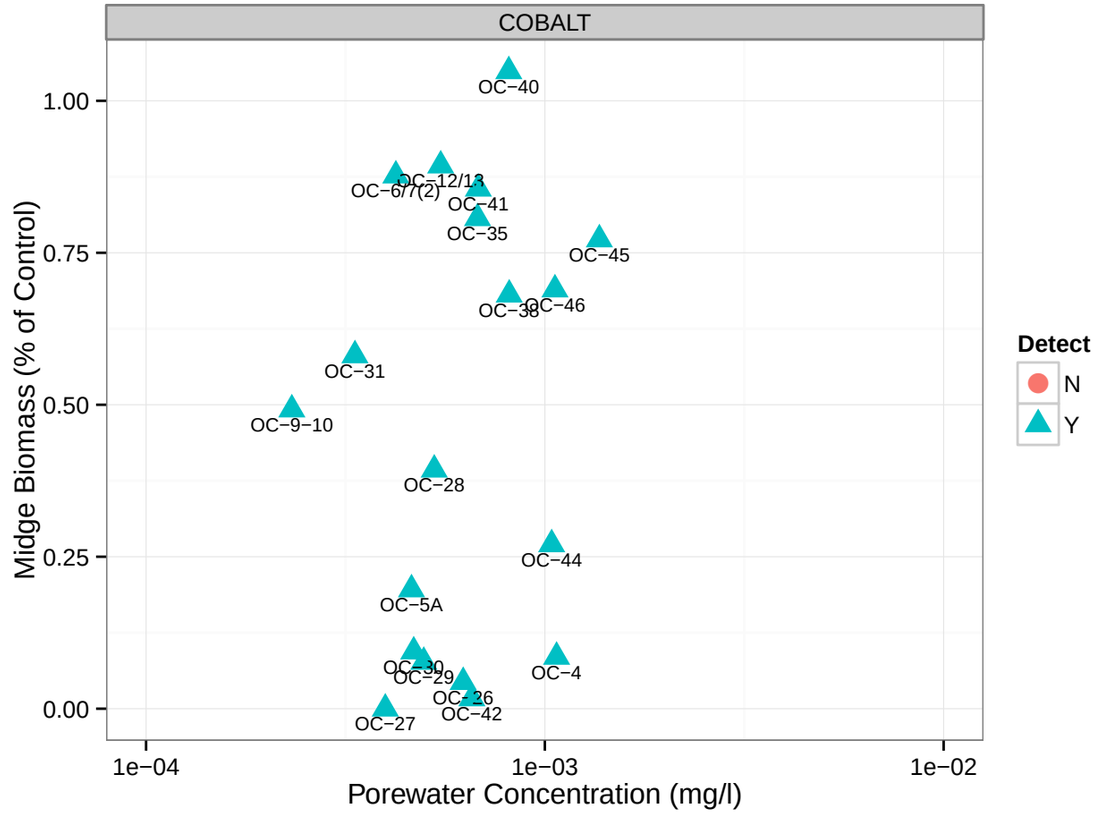


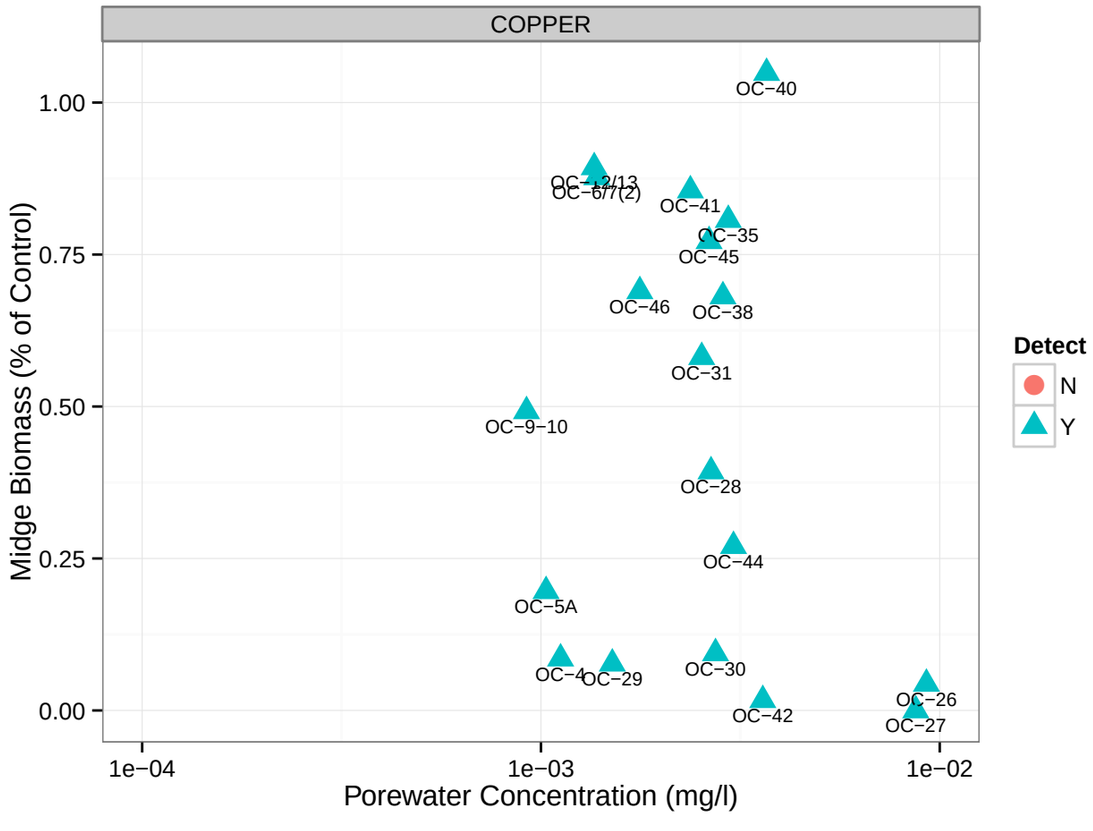


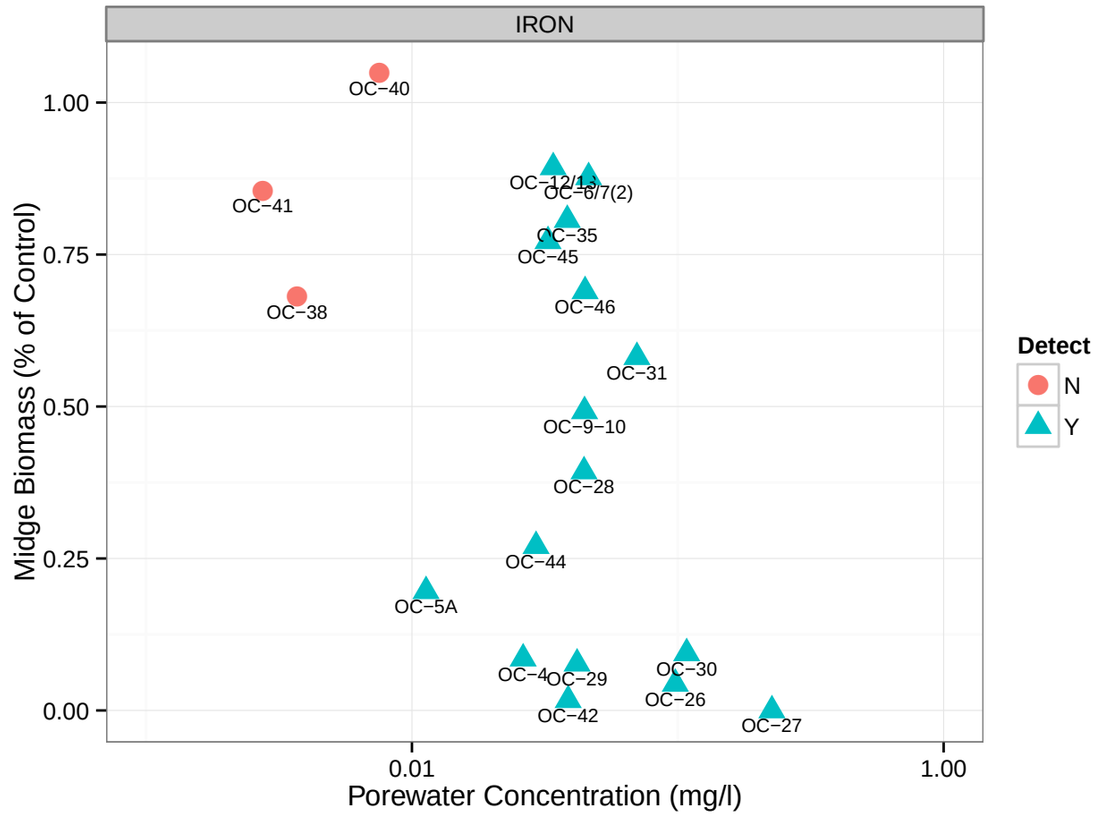




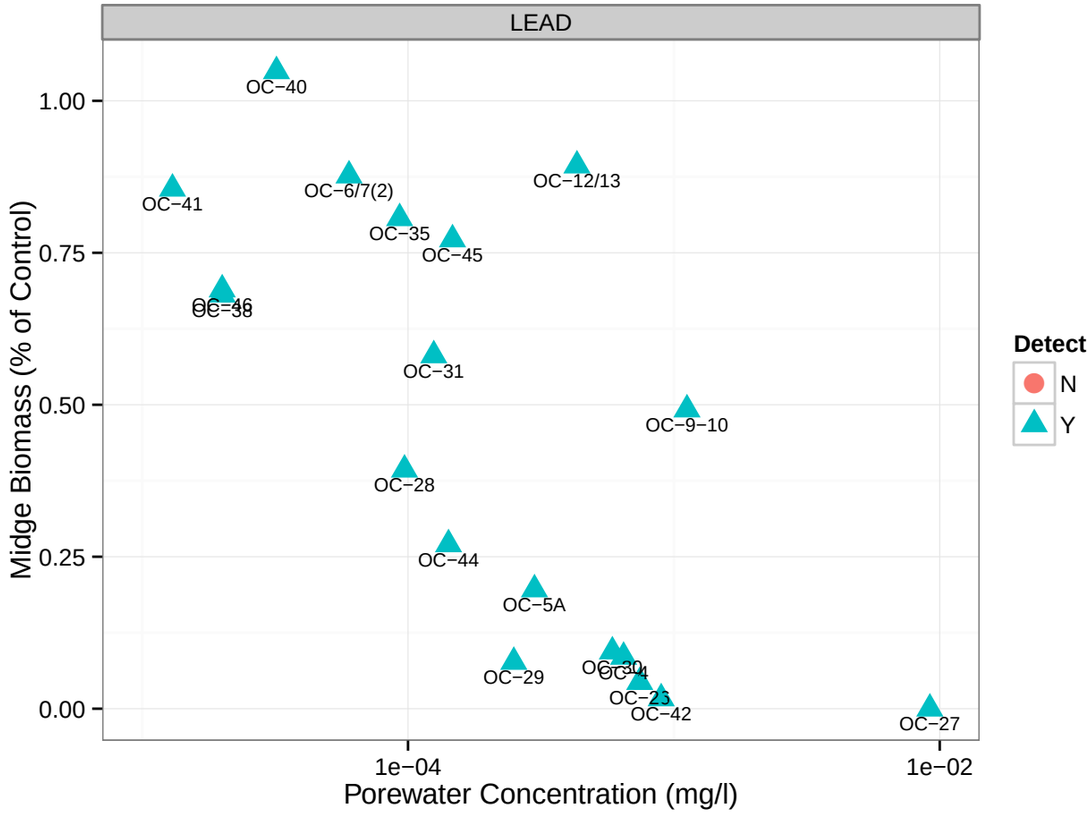

CHROMIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−12/13
OC−41
OC−6/7(2)
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−30
OC−4
OC−26
OC−42
OC−27
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
Detect
N
Y

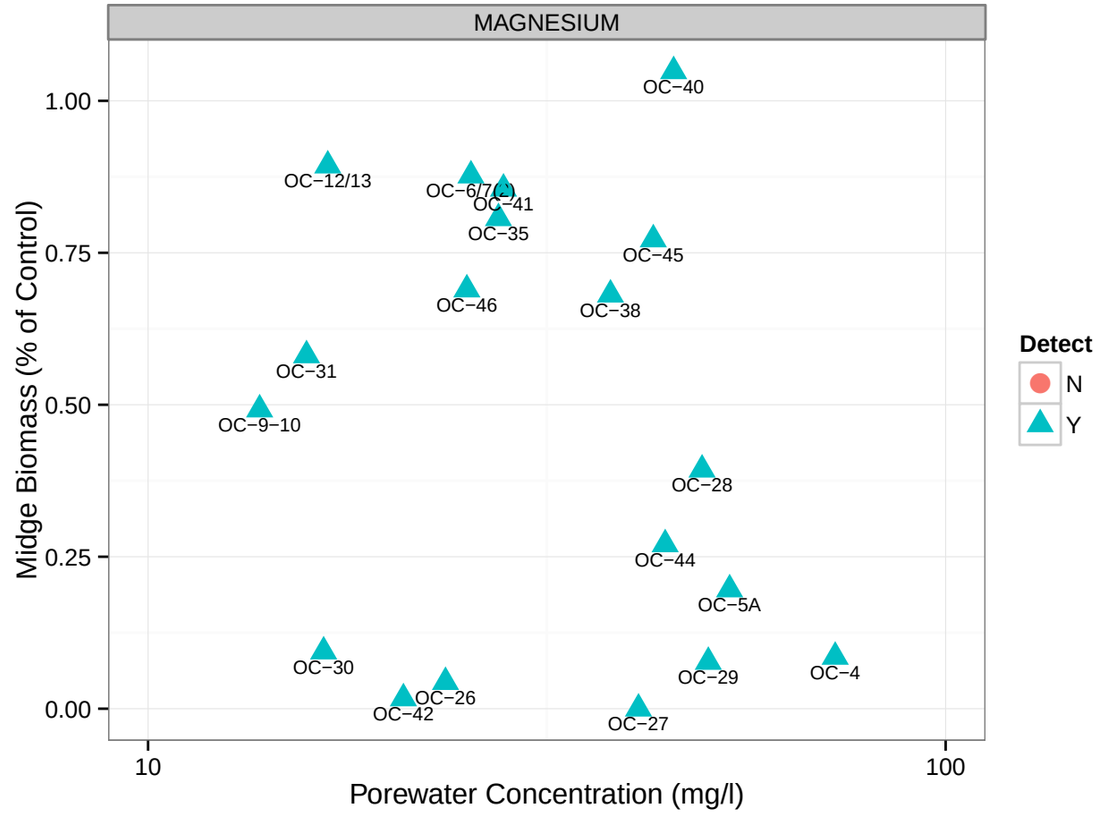

COBALT
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−6/7(2)
OC−12/13
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
Detect
N
Y

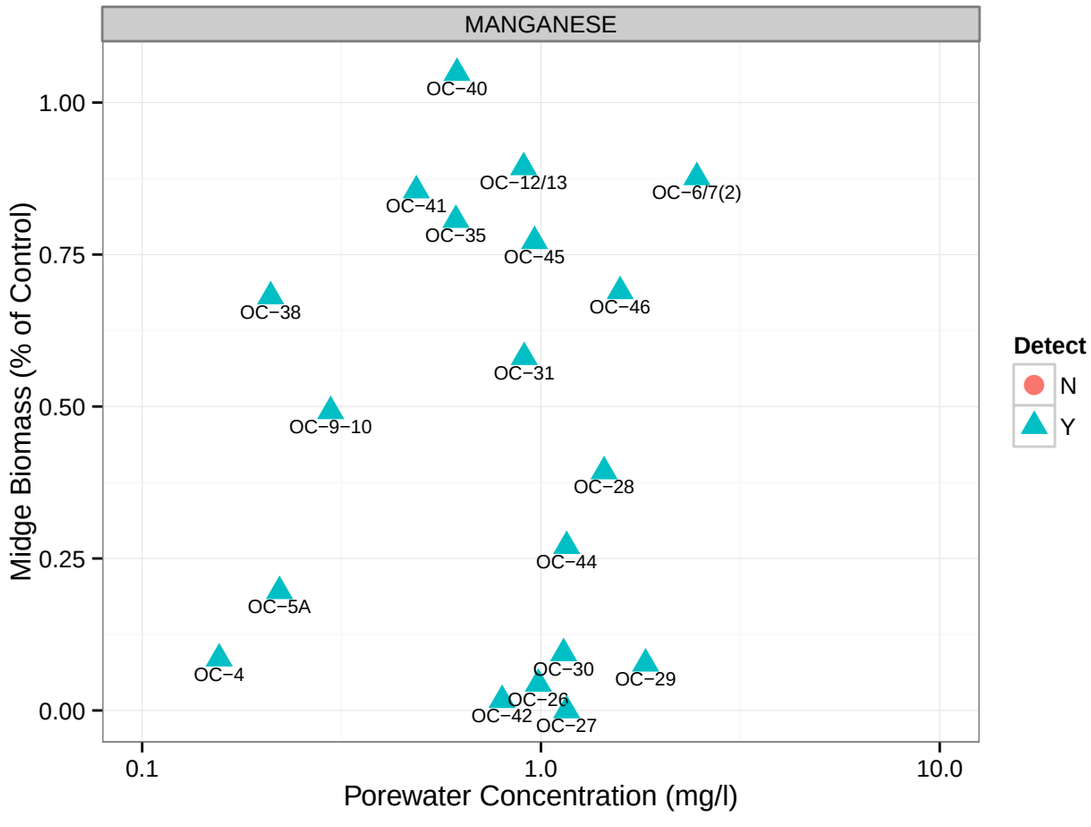

COPPER
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−42
OC−26
OC−27
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
Detect
N
Y

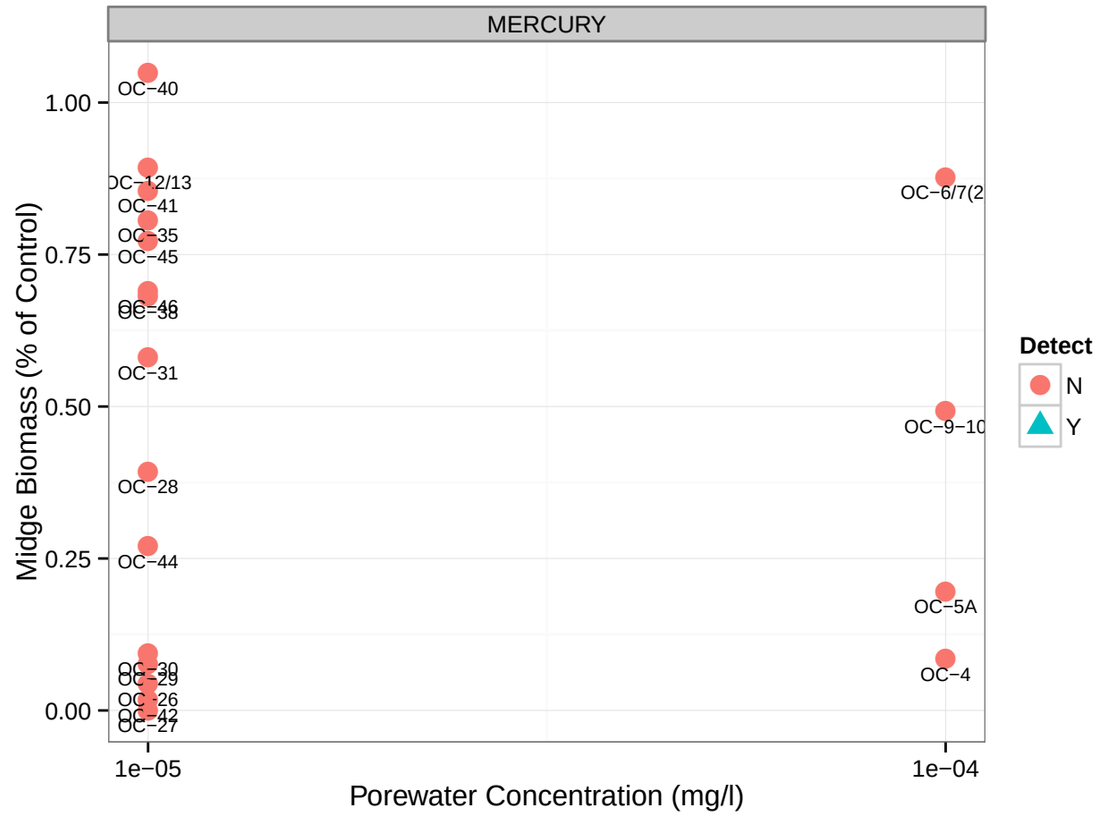

IRON
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
OC−40
OC−41
OC−12/13
OC−6/7(2)
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−29
OC−30
OC−26
OC−42
OC−27
0.01
1.00
Porewater Concentration (mg/l)
Detect
N
Y

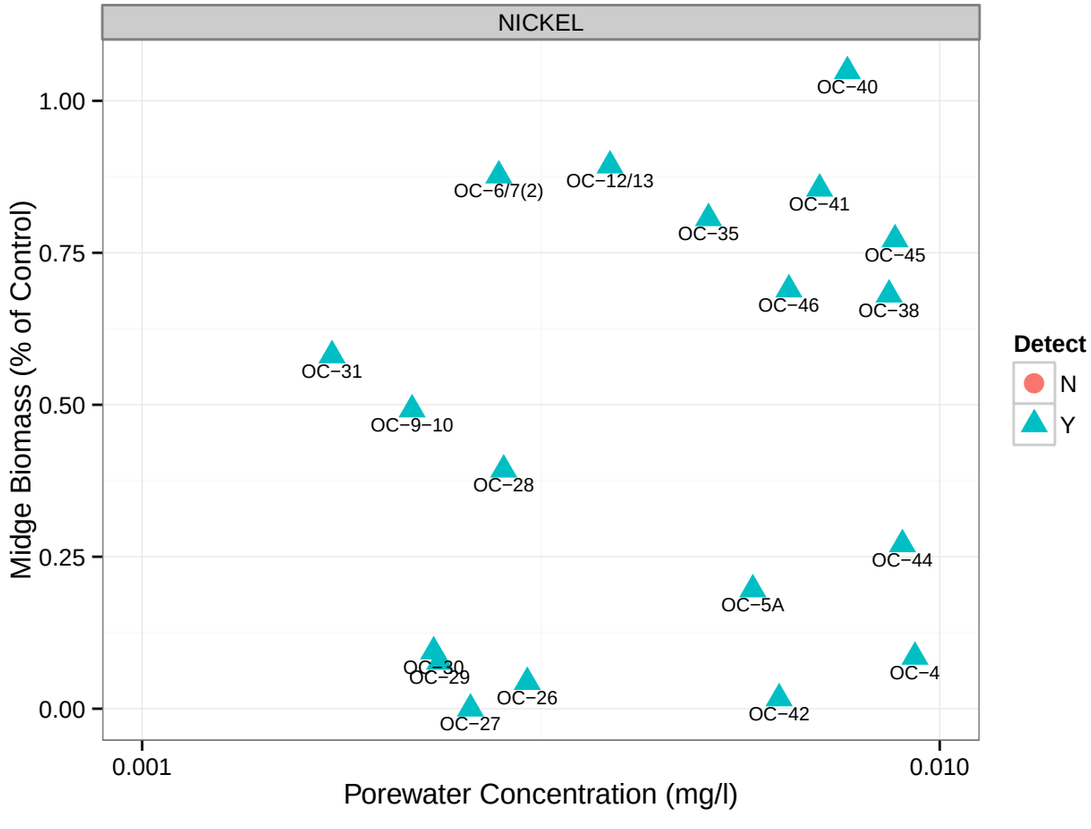
Attachment 2b: Analtyical Parameters versus Midge Biomass, Lower Otter Creek Only

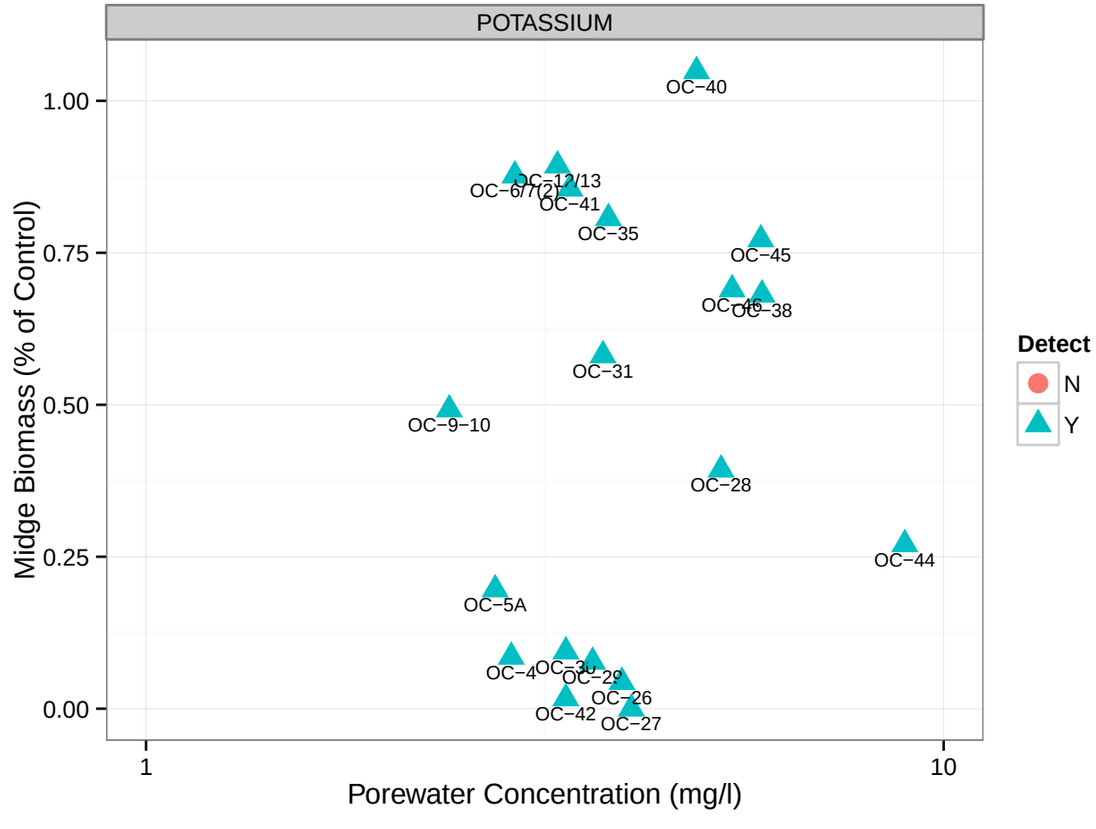


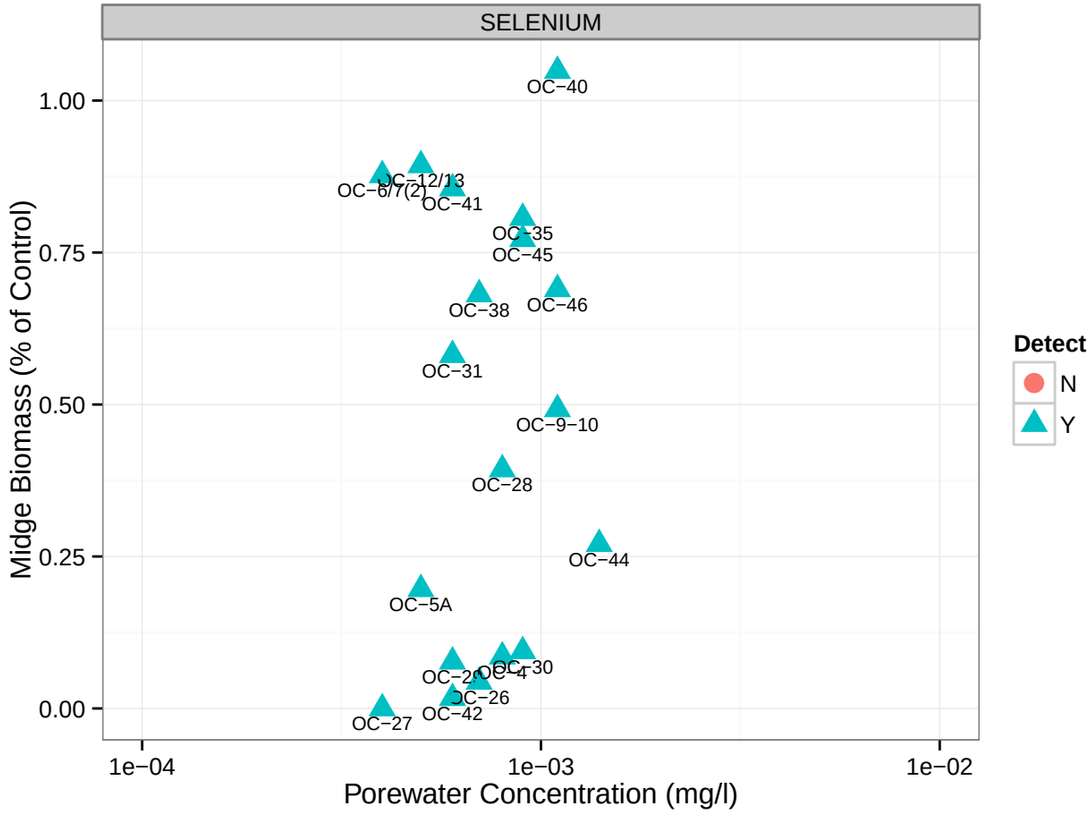


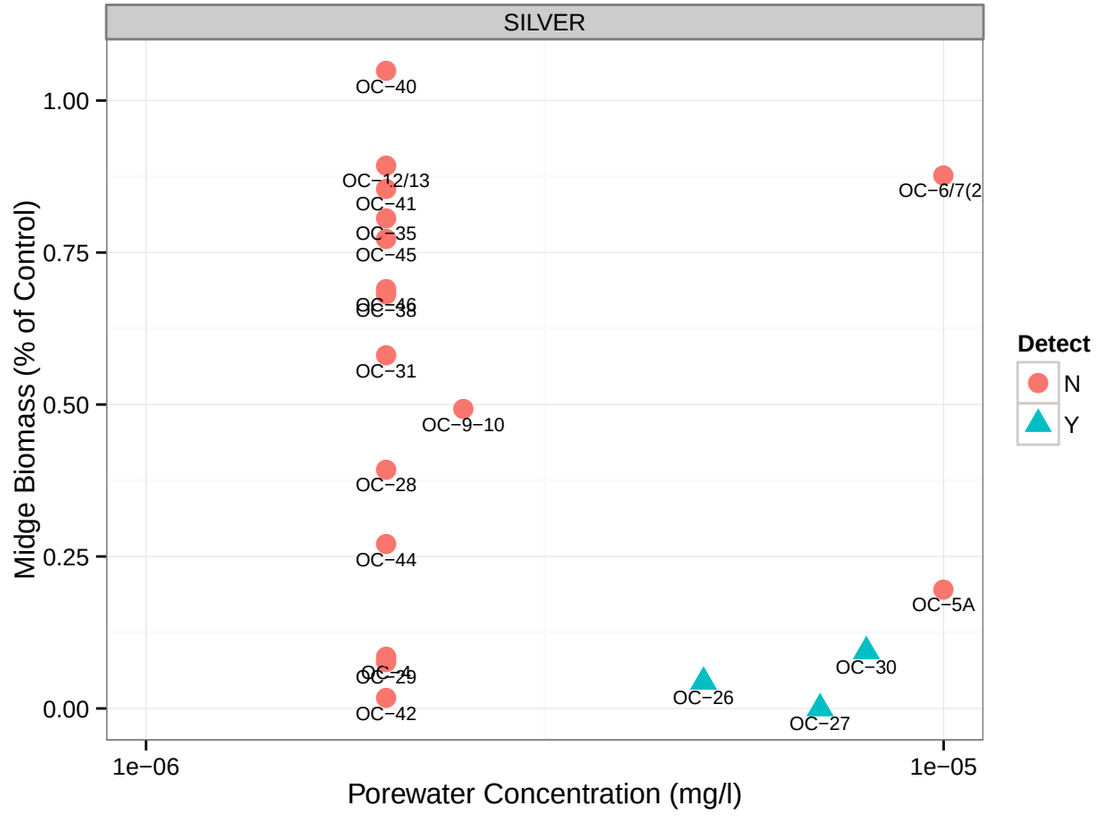


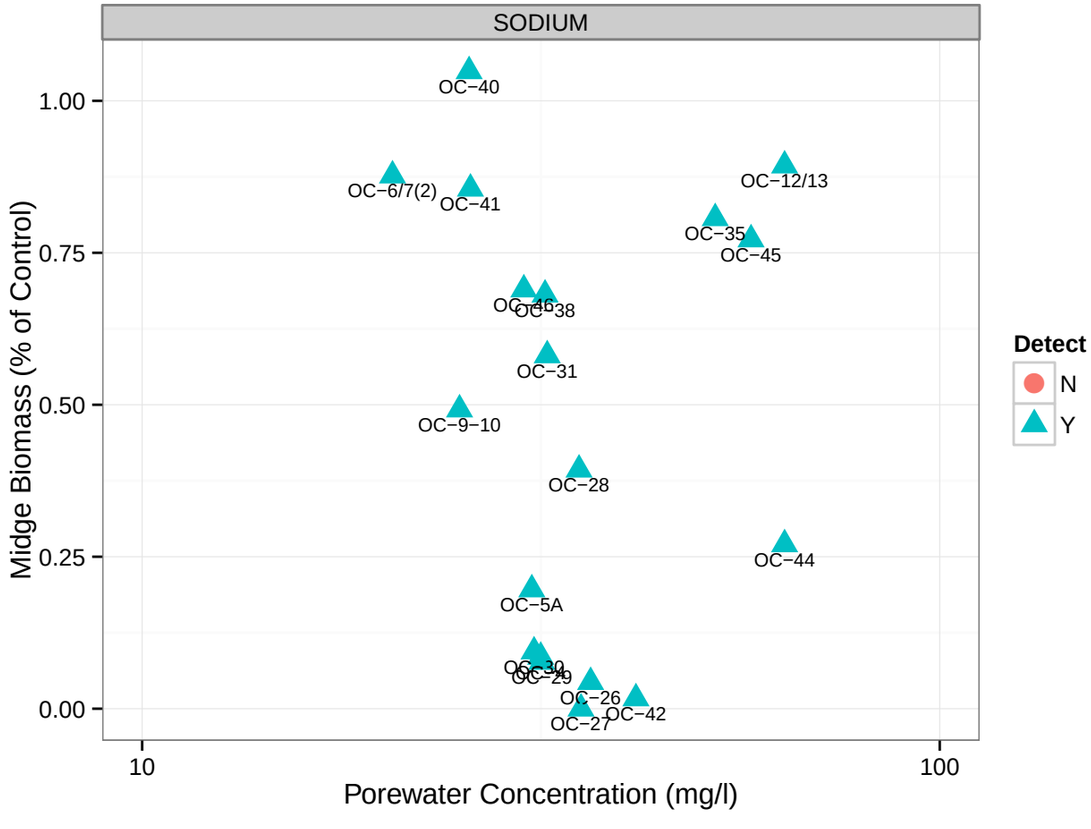


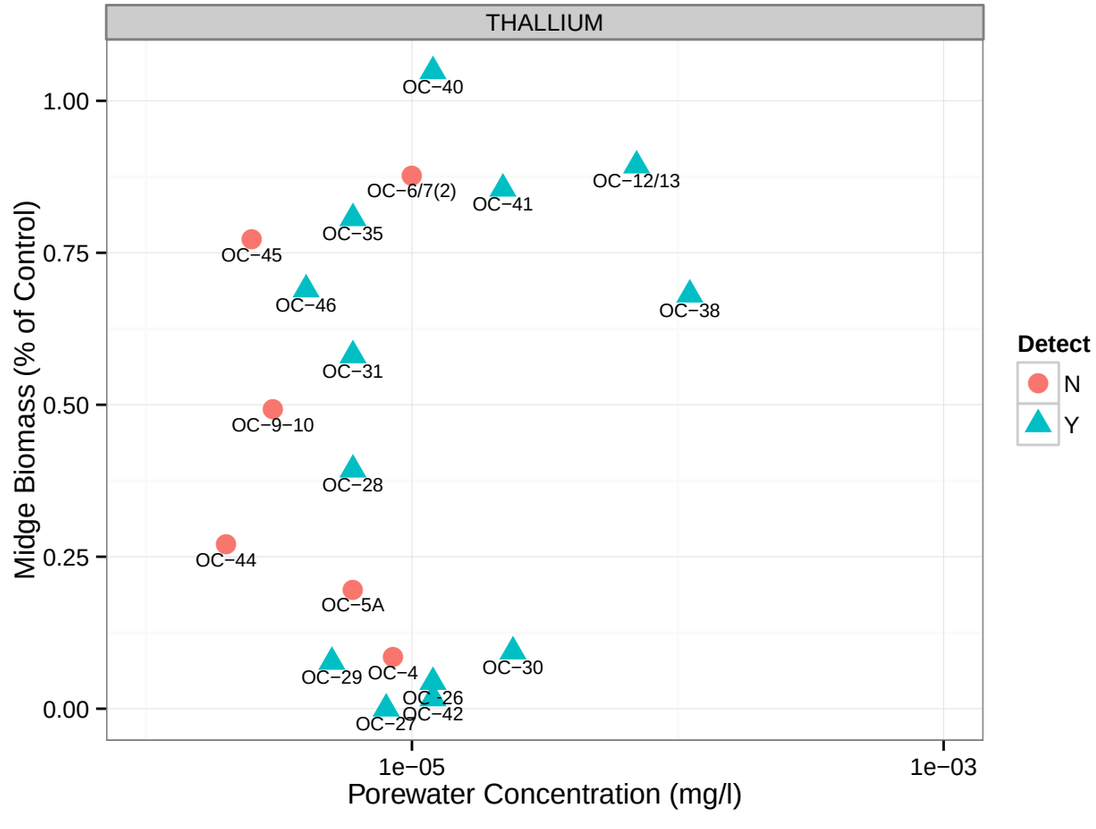

NICKEL
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.001
0.010
Porewater Concentration (mg/l)
OC−40
OC−6/7(2)
OC−12/13
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−26
OC−27
OC−42
OC−4
Detect
N
Y

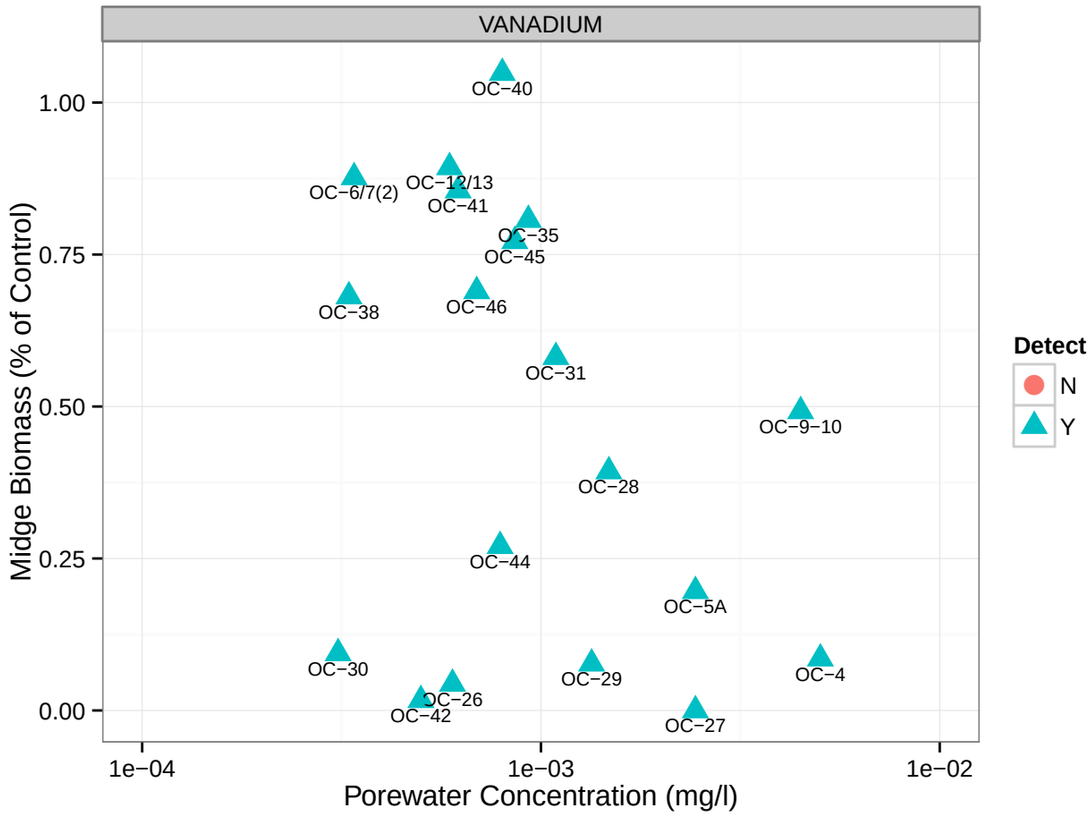

POTASSIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1
10
Porewater Concentration (mg/l)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−4
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

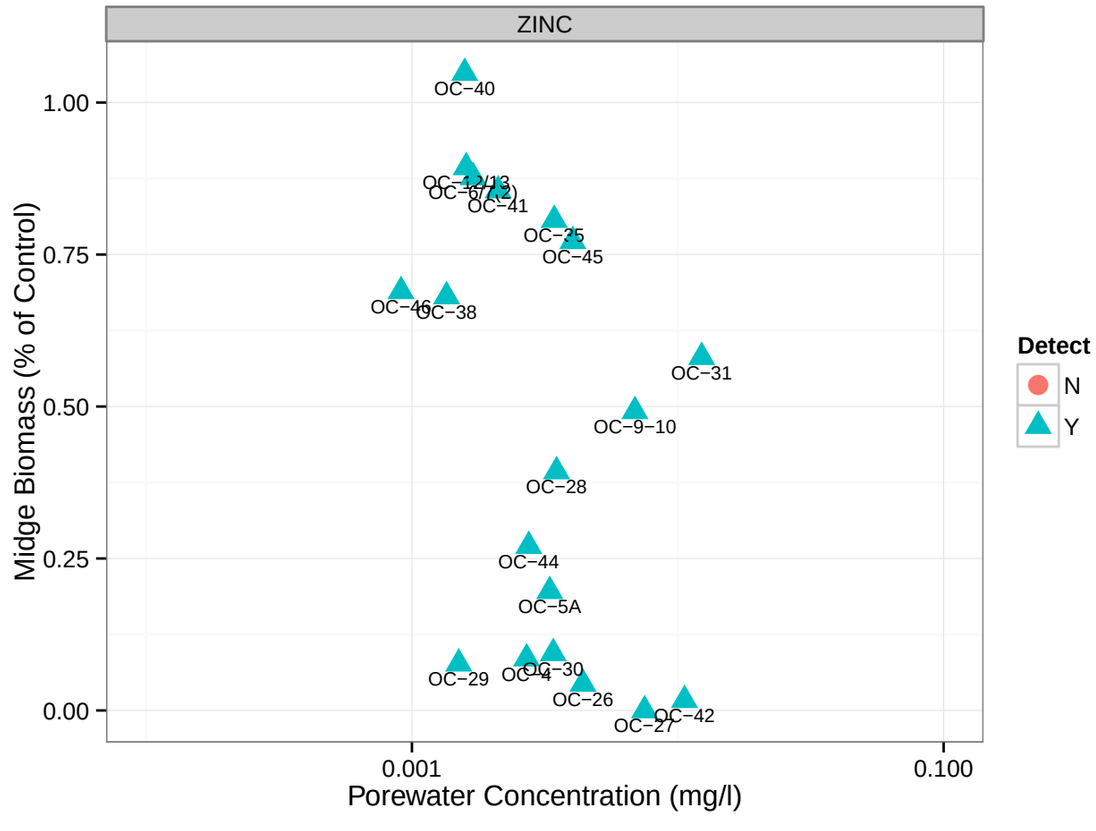

SELENIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
OC−40
OC−6/7(2)
OC−12/13
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−4
OC−26
OC−42
OC−27
Detect
N
Y


SILVER
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e−06
1e−05
Porewater Concentration (mg/l)
OC−40
OC−12/13
OC−6/7(2
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

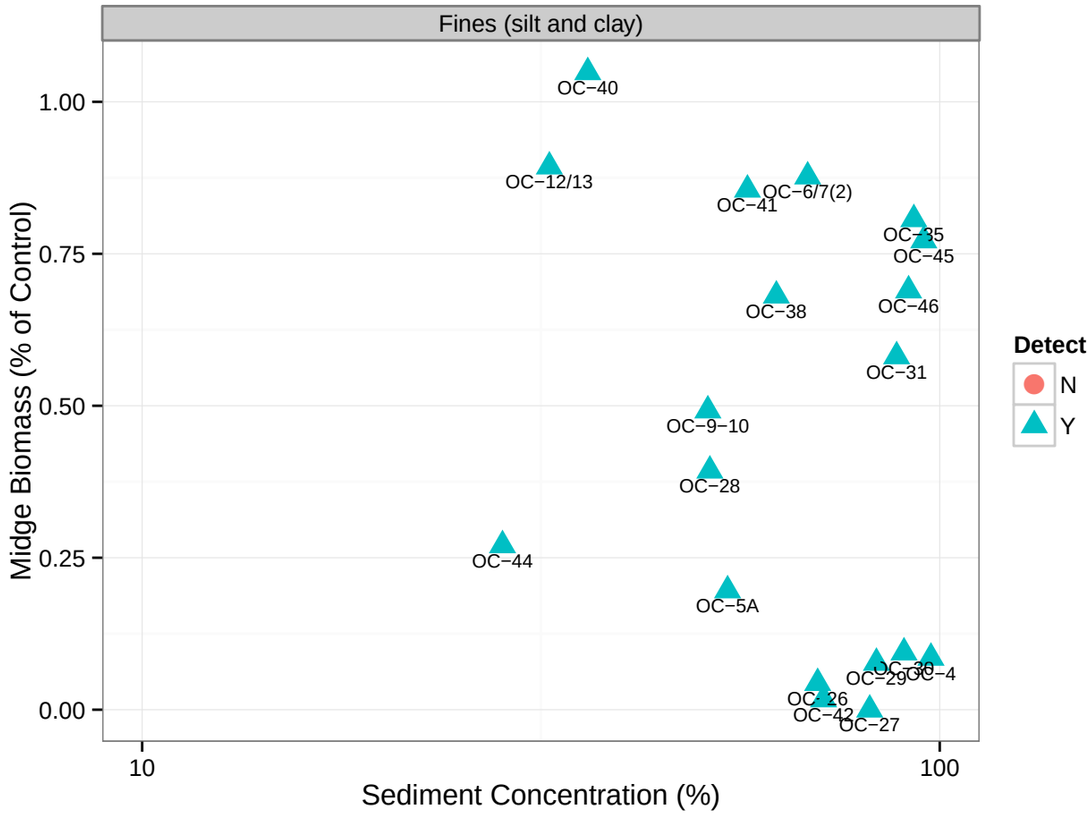

SODIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
10
100
Porewater Concentration (mg/l)
OC−40
OC−6/7(2)
OC−41
OC−12/13
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−26
OC−42
OC−27
Detect
N
Y

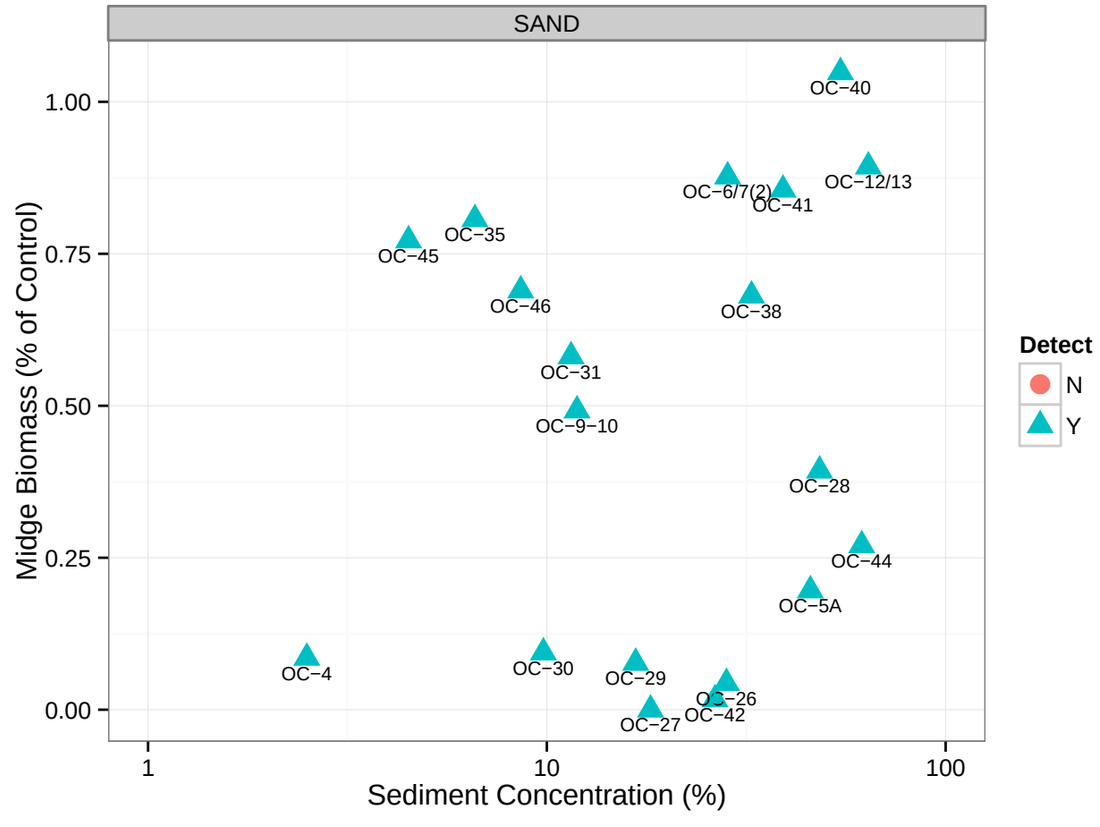

THALLIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e−05
1e−03
Porewater Concentration (mg/l)
OC−40
OC−6/7(2)
OC−41
OC−12/13
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−4
OC−26
OC−30
OC−42
OC−27
Detect
N
Y

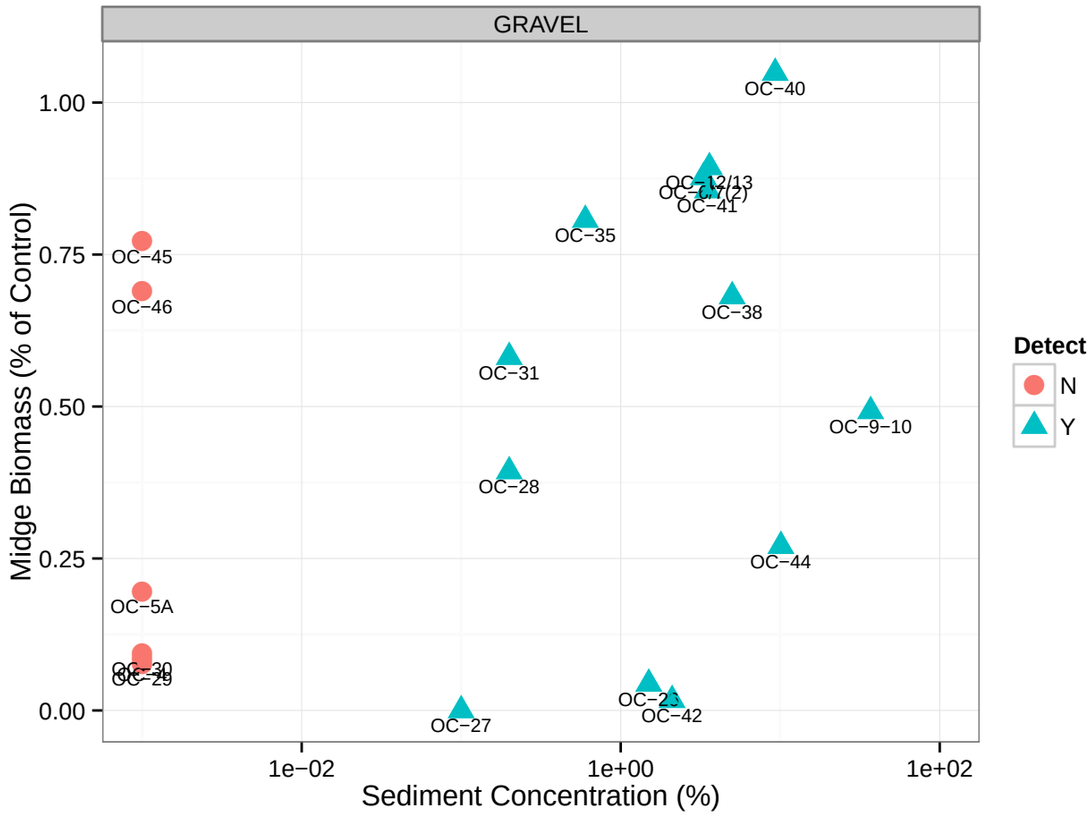

VANADIUM
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
1e−04
1e−03
1e−02
Porewater Concentration (mg/l)
OC−40
OC−6/7(2)
OC−12/13
OC−41
OC−35
OC−45
OC−38
OC−46
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−30
OC−29
OC−4
OC−26
OC−42
OC−27
Detect
N
Y


ZINC
Midge Biomass (% of Control)
1.00
0.75
0.50
0.25
0.00
0.001
0.100
Porewater Concentration (mg/l)
OC−40
OC−12/13
OC−6/7(2)
OC−41
OC−35
OC−45
OC−46
OC−38
OC−31
OC−9−10
OC−28
OC−44
OC−5A
OC−29
OC−4
OC−30
OC−26
OC−27
OC−42
Detect
N
Y

Attachment 2b: Analtyical Parameters versus Midge Biomass, Lower Otter Creek Only

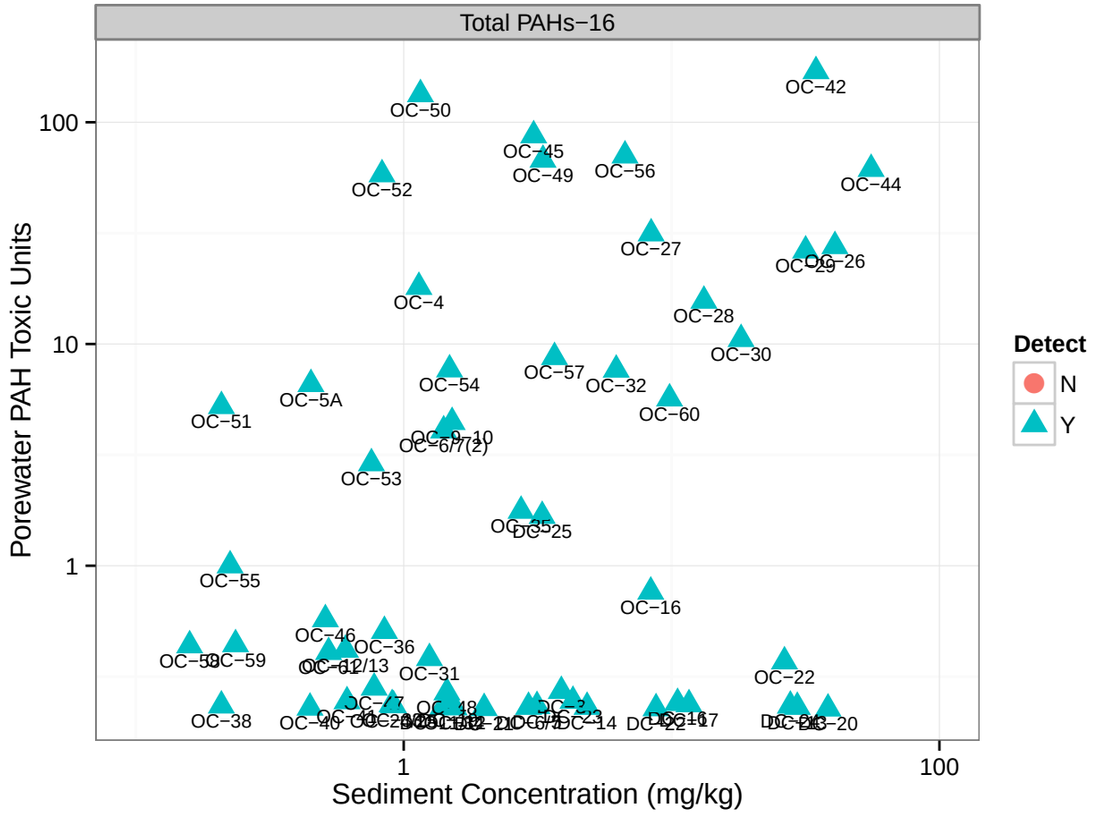


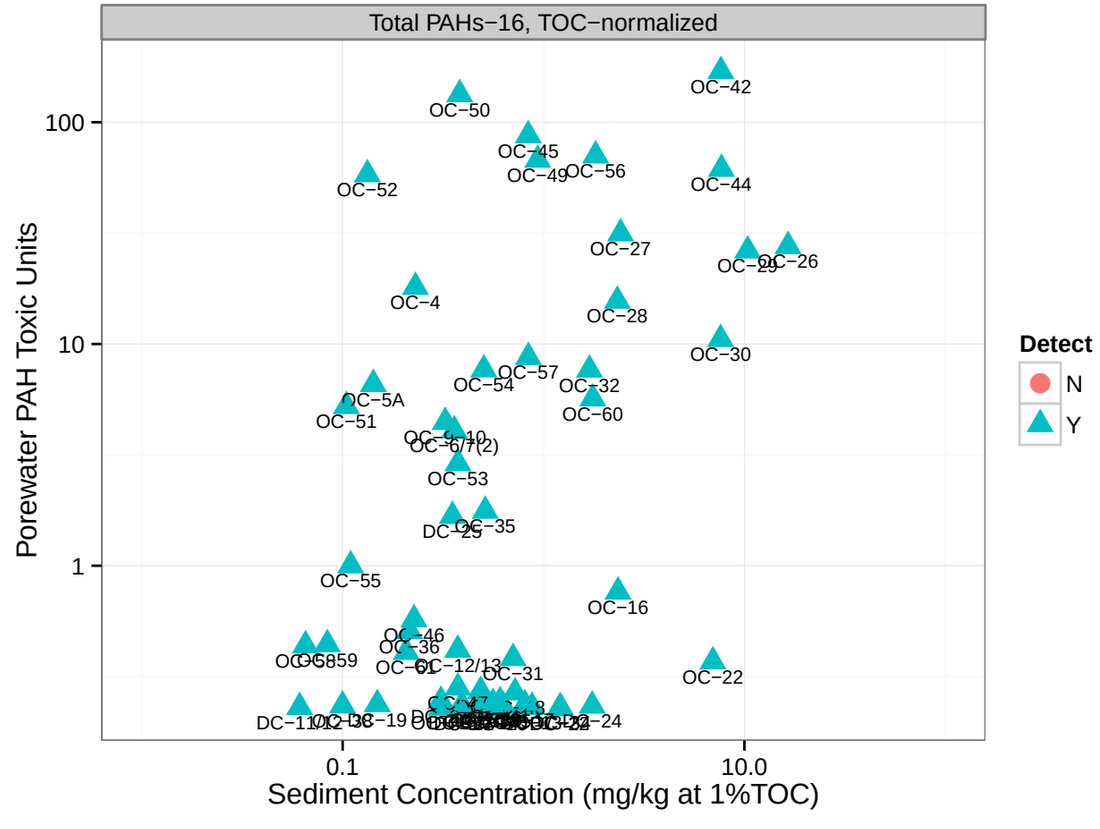


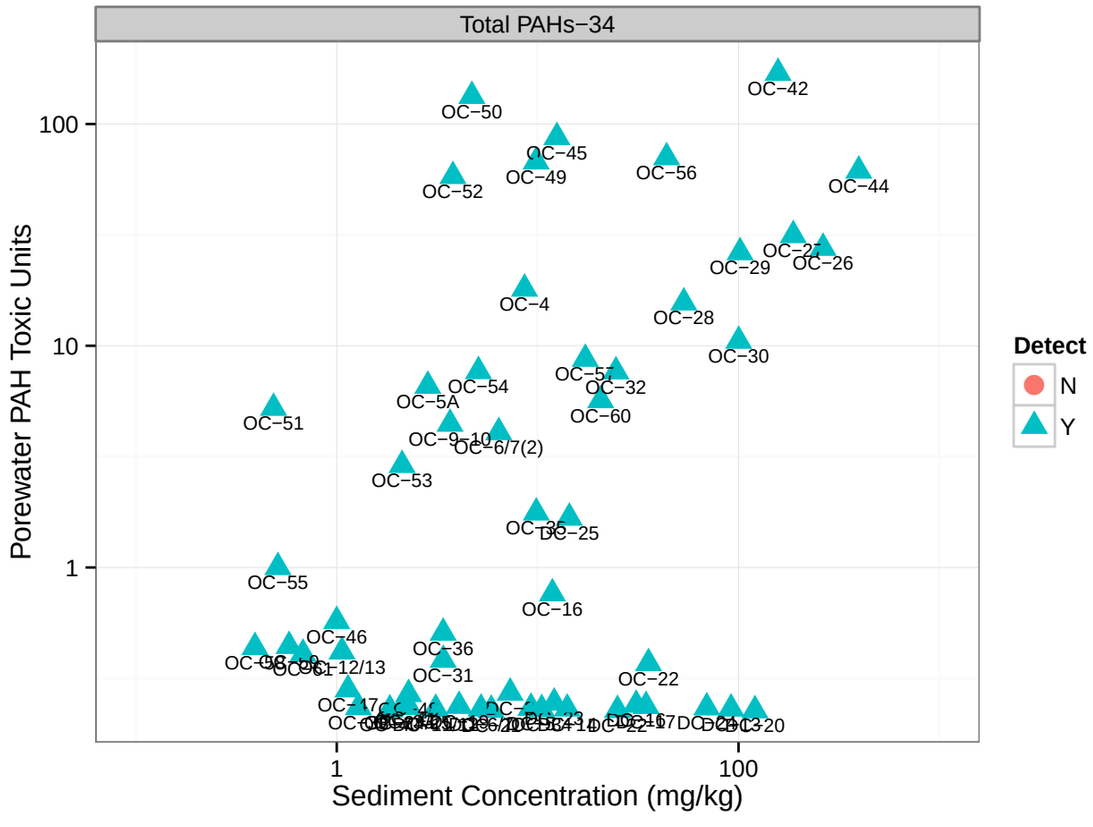


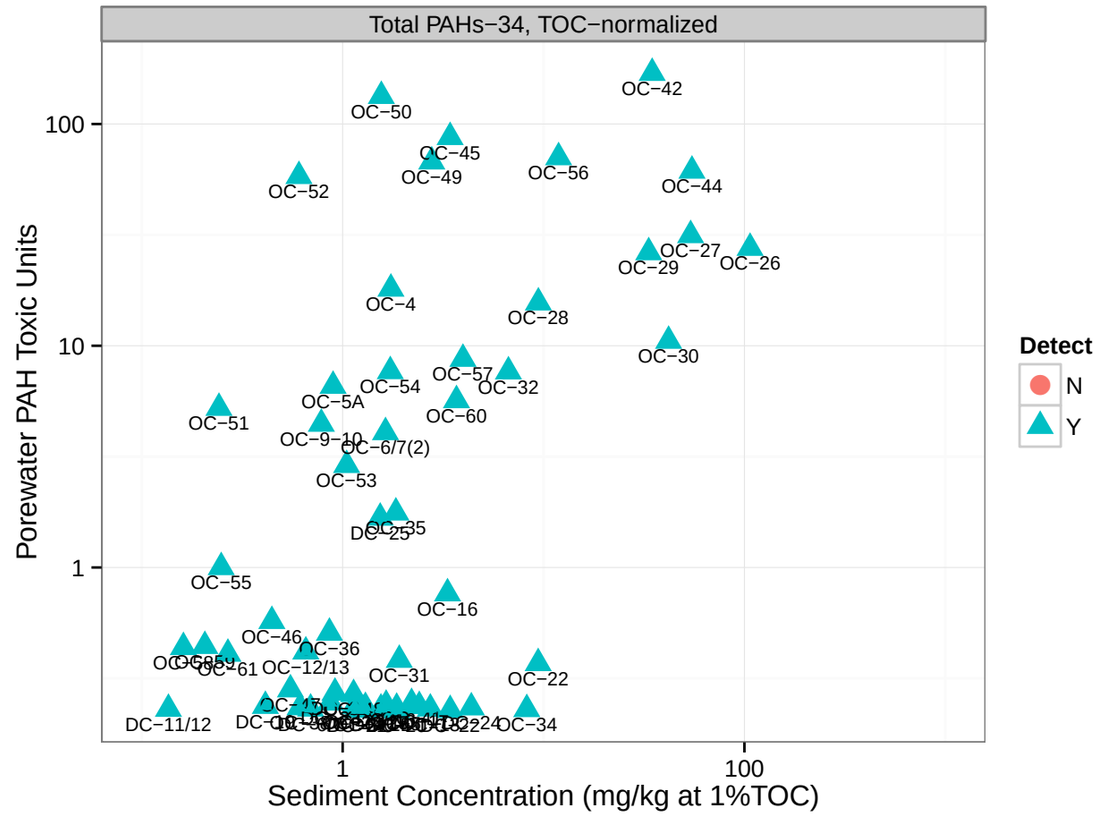
Attachment 3

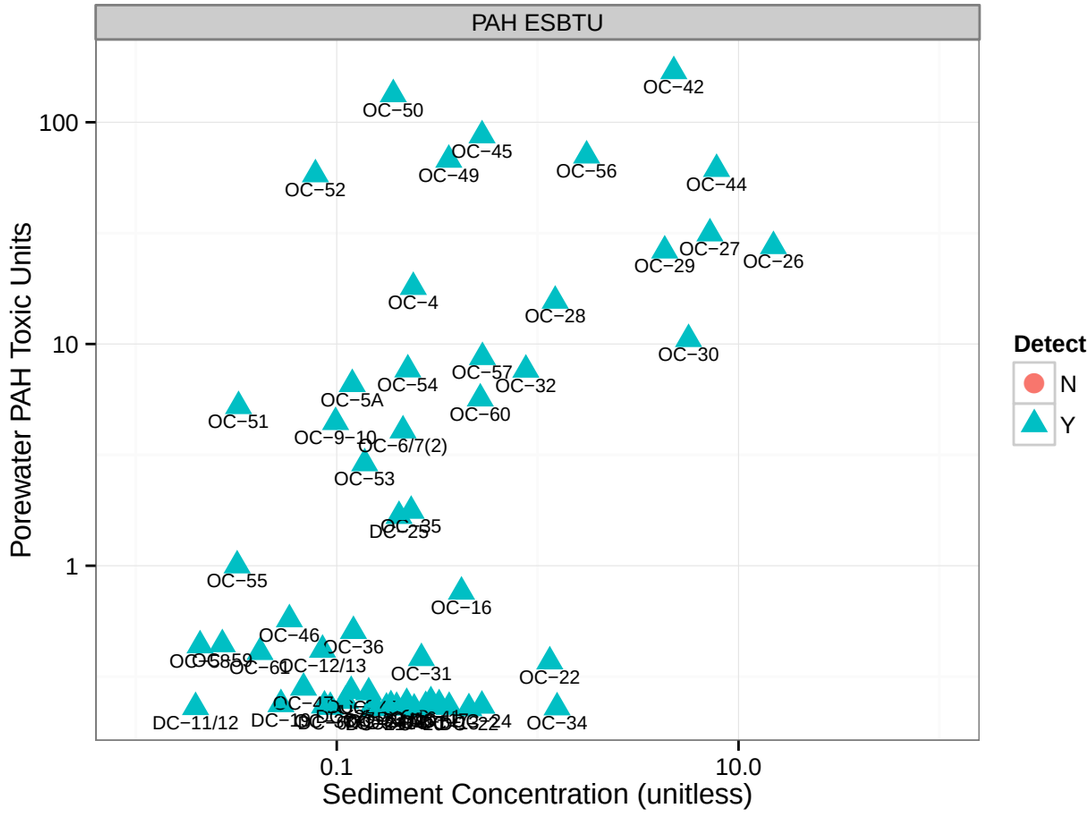
Graphs of Sediment Analytical Parameters versus Porewater PAH Toxic Units

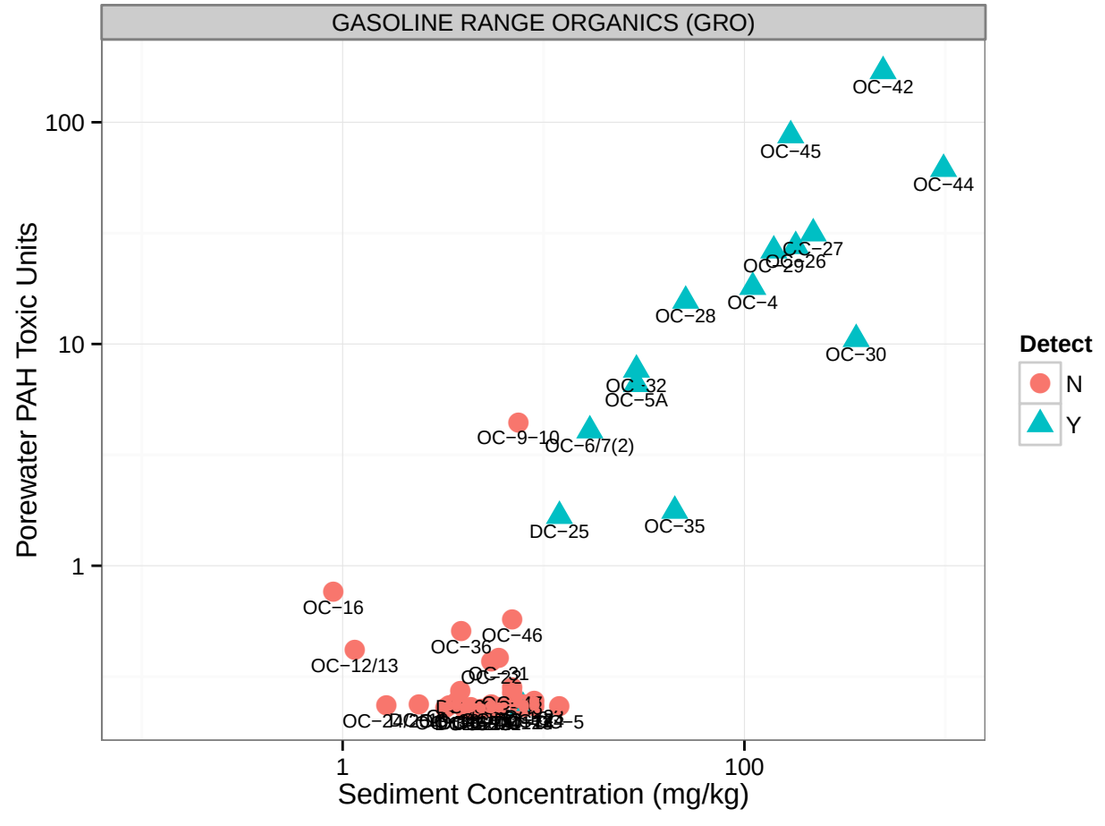

Total PAHs−16
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg)
1
100
Detect
N
Y

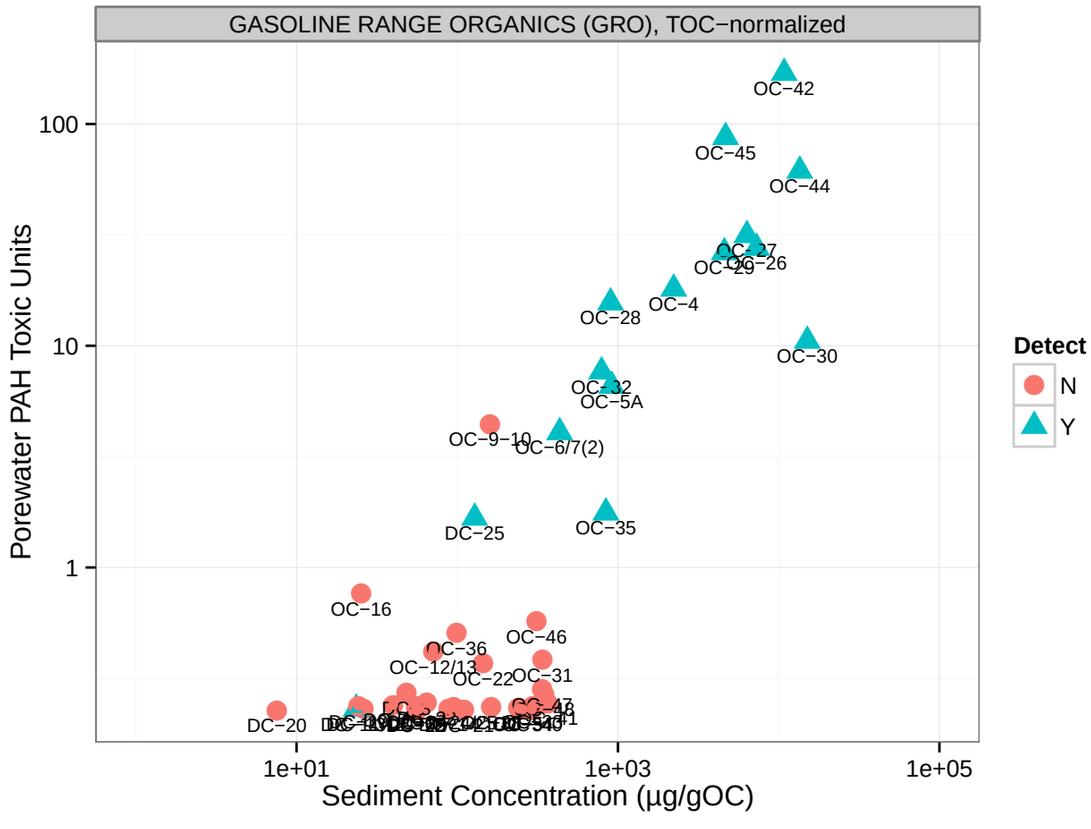

Total PAHs−16, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg at 1%TOC)
0.1
10.0
Detect
N
Y

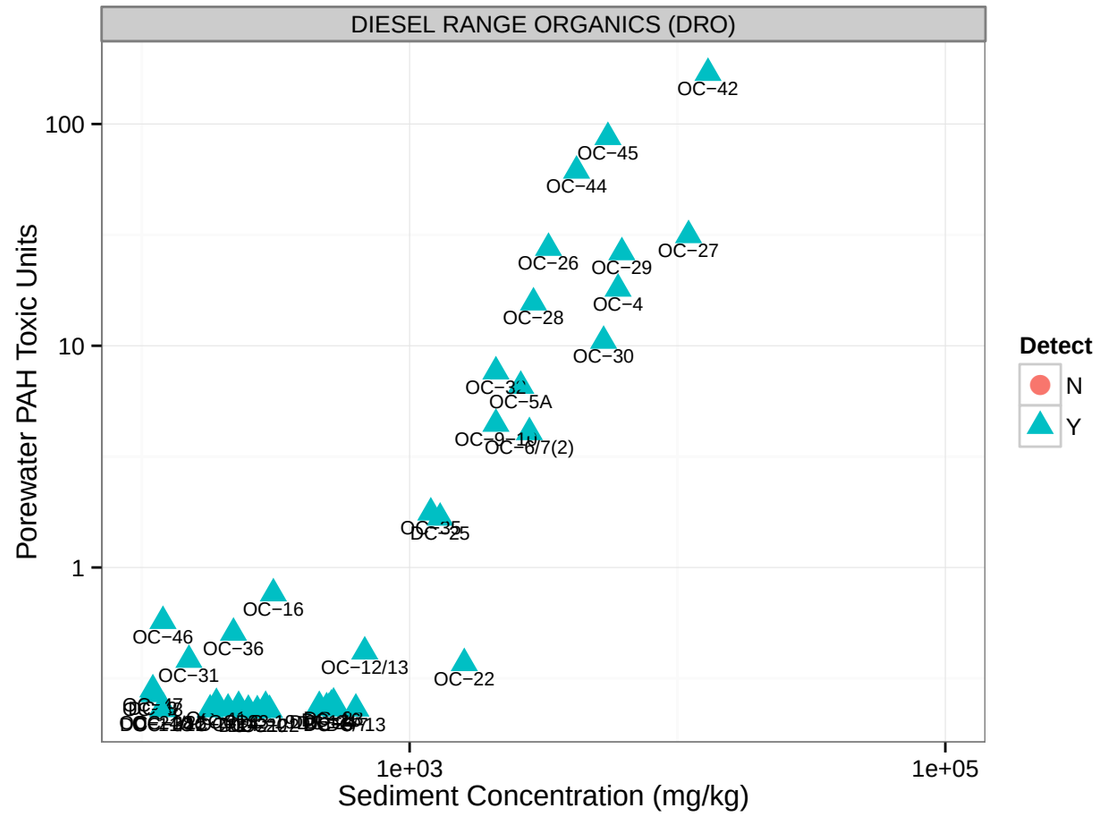

Total PAHs−34
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg)
1
100
Detect
N
Y

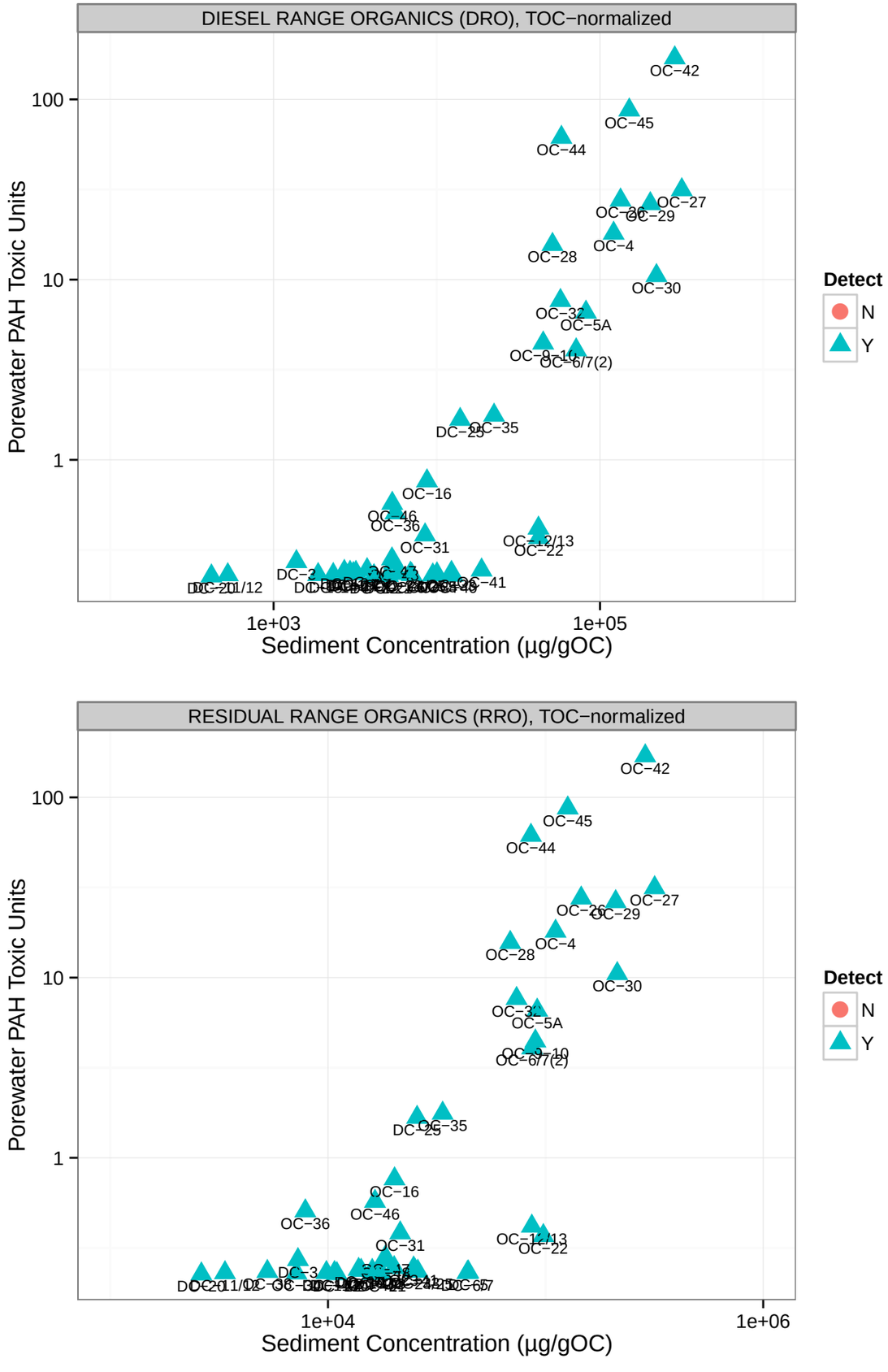

Total PAHs−34, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg at 1%TOC)
1
100
Detect
N
Y

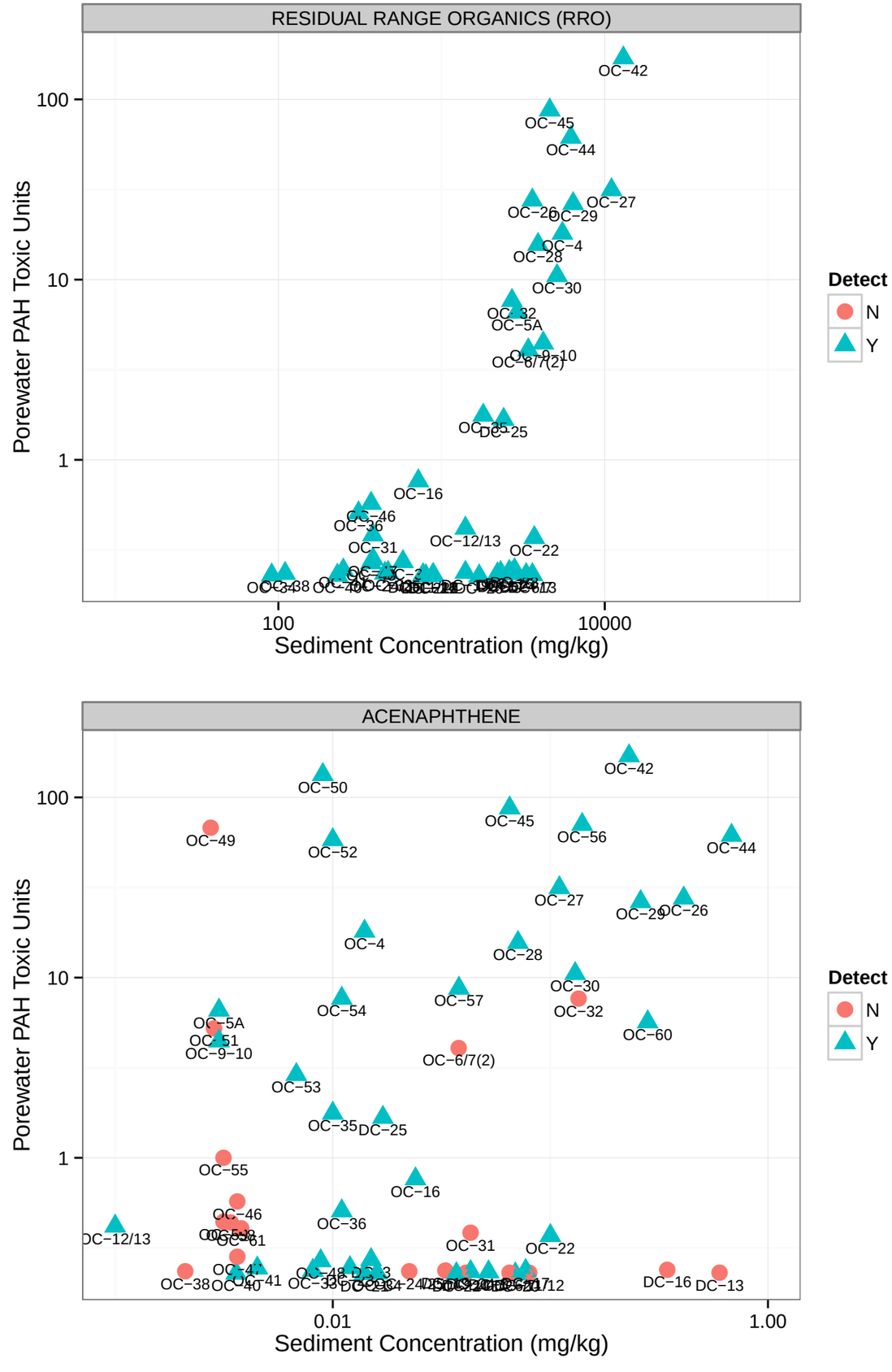

PAH ESBTU
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (unitless)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
DC−25
OC−55
OC−16
OC−46
OC−36
OC−12/13
OC−31
OC−22
DC−11/12
OC−34
Detect
N
Y


GASOLINE RANGE ORGANICS (GRO)
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (mg/kg)
OC−42
OC−45
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9−10
OC−6/7(2)
DC−25
OC−35
OC−16
OC−46
OC−36
OC−12/13
OC−31
OC−22
Detect
N
Y


GASOLINE RANGE ORGANICS (GRO), TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e+01
1e+03
1e+05
Sediment Concentration (µg/gOC)
OC−42
OC−45
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9−10
OC−6/7(2)
DC−25
OC−35
OC−16
OC−46
OC−36
OC−12/13
OC−22
OC−31
DC−20
Detect
N
Y

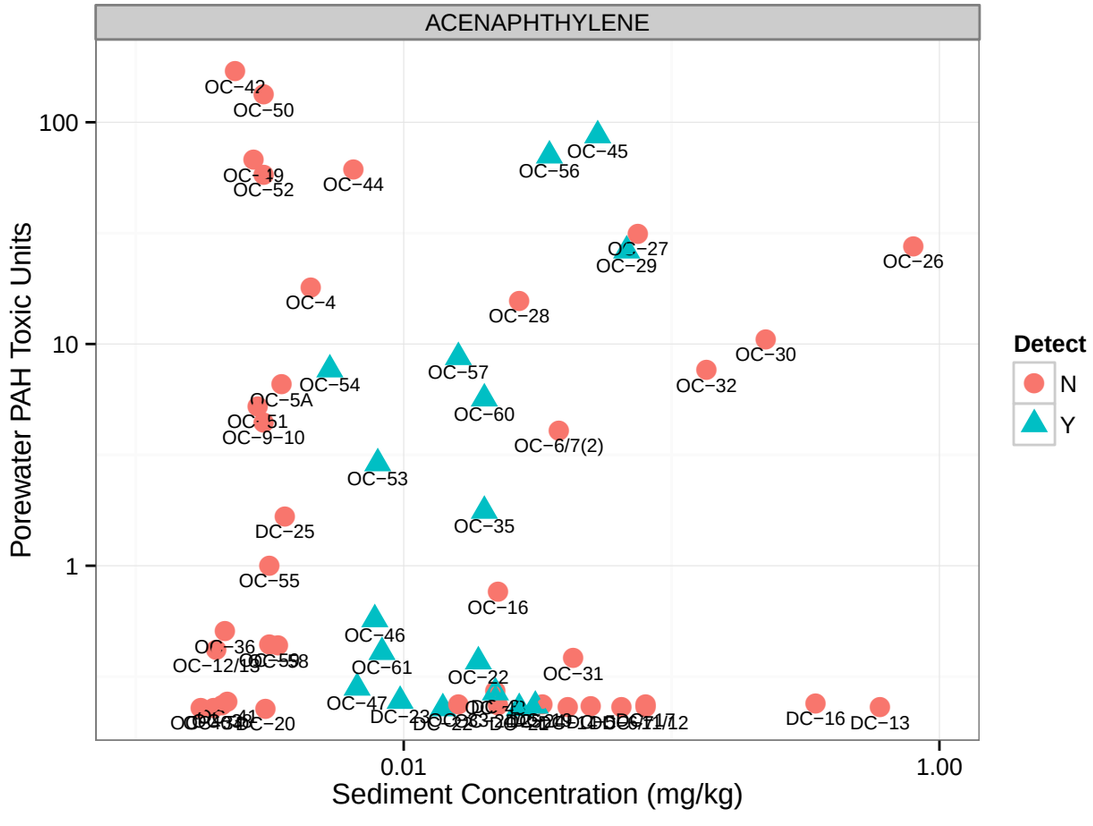

DIESEL RANGE ORGANICS (DRO)
Porewater PAH Toxic Units
100
10
1
1e+03
1e+05
Sediment Concentration (mg/kg)
OC−42
OC−45
OC−44
OC−26
OC−29
OC−27
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9−10
OC−6/7(2)
OC−35
DC−25
OC−16
OC−46
OC−36
OC−12/13
OC−31
OC−22
Detect
N
Y

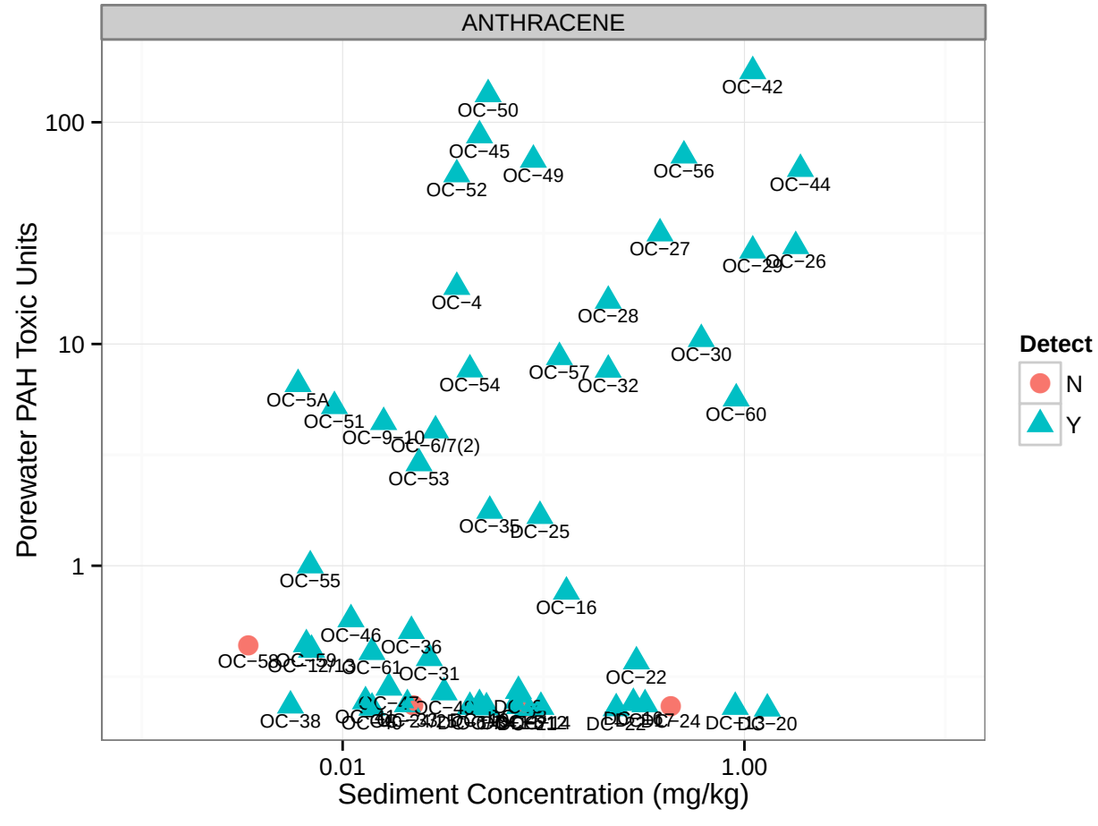

DIESEL RANGE ORGANICS (DRO), TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e+03
1e+05
Sediment Concentration (µg/gOC)
Detect
N
Y

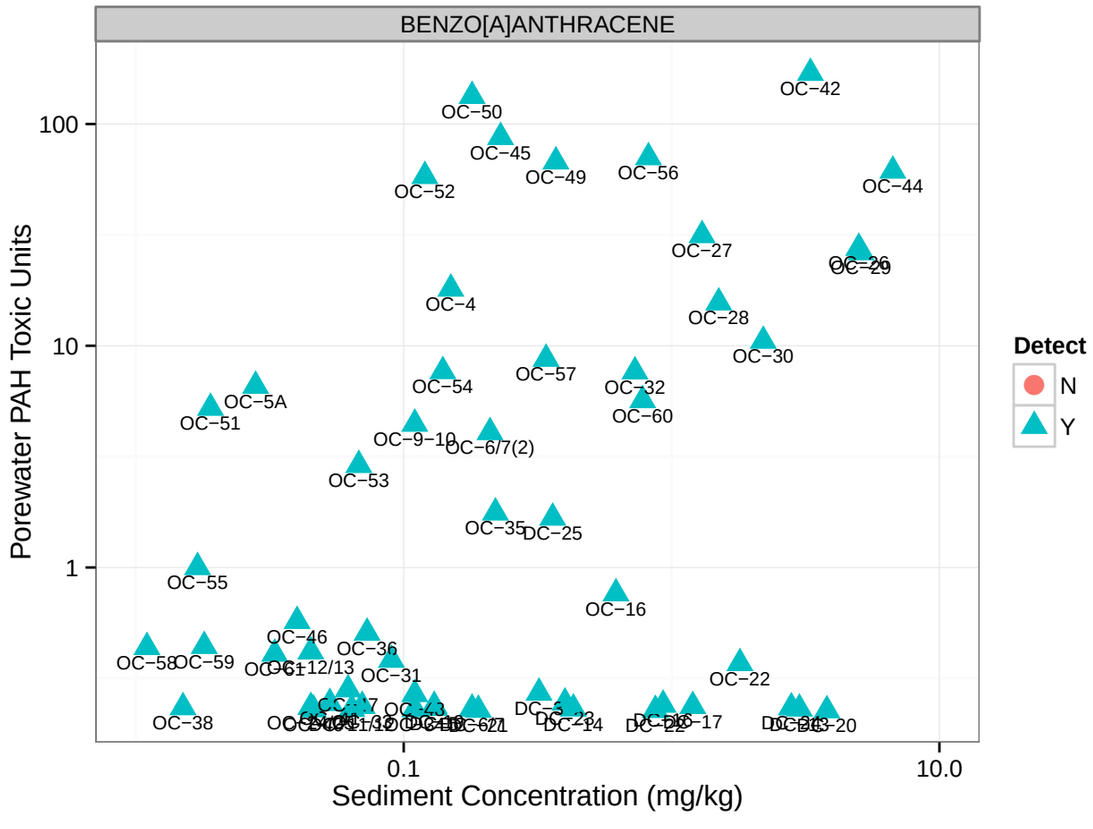

RESIDUAL RANGE ORGANICS (RRO)
Porewater PAH Toxic Units
100
10
1
100
10000
Sediment Concentration (mg/kg)
Detect
N
Y

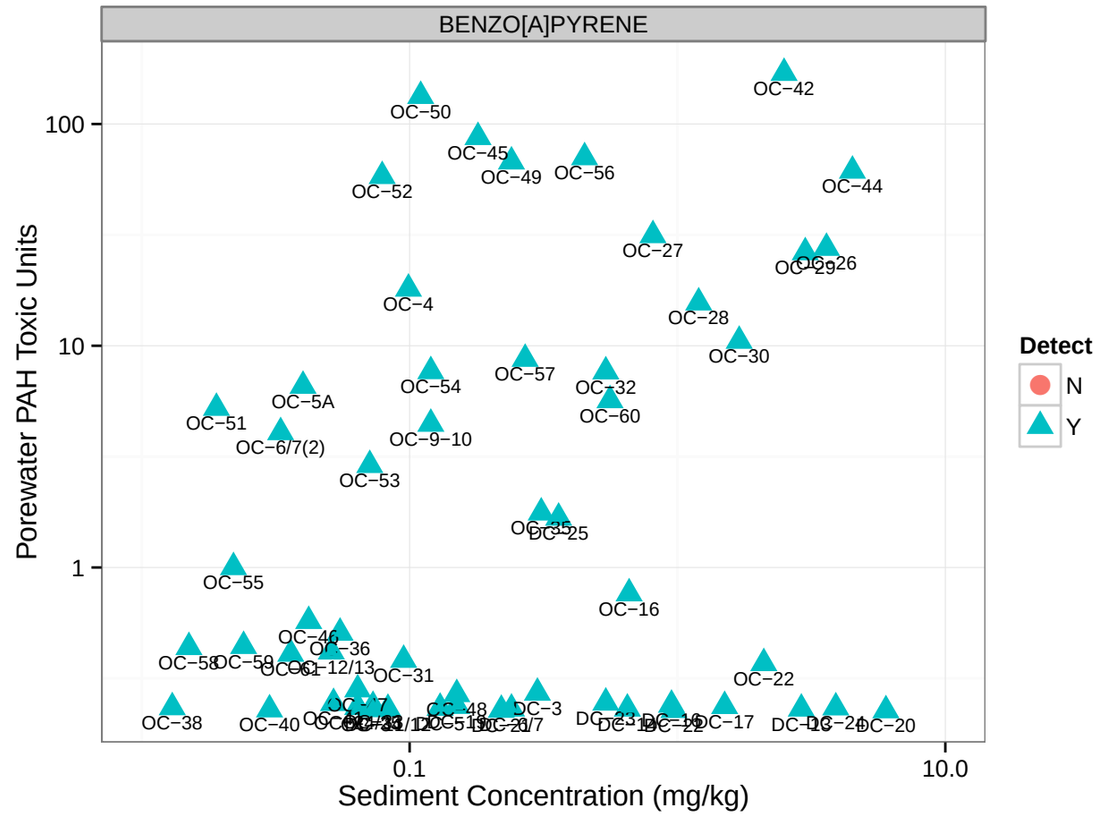
RESIDUAL RANGE ORGANICS (RRO), TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e+04
1e+06
Sediment Concentration (µg/gOC)
Detect
N
Y

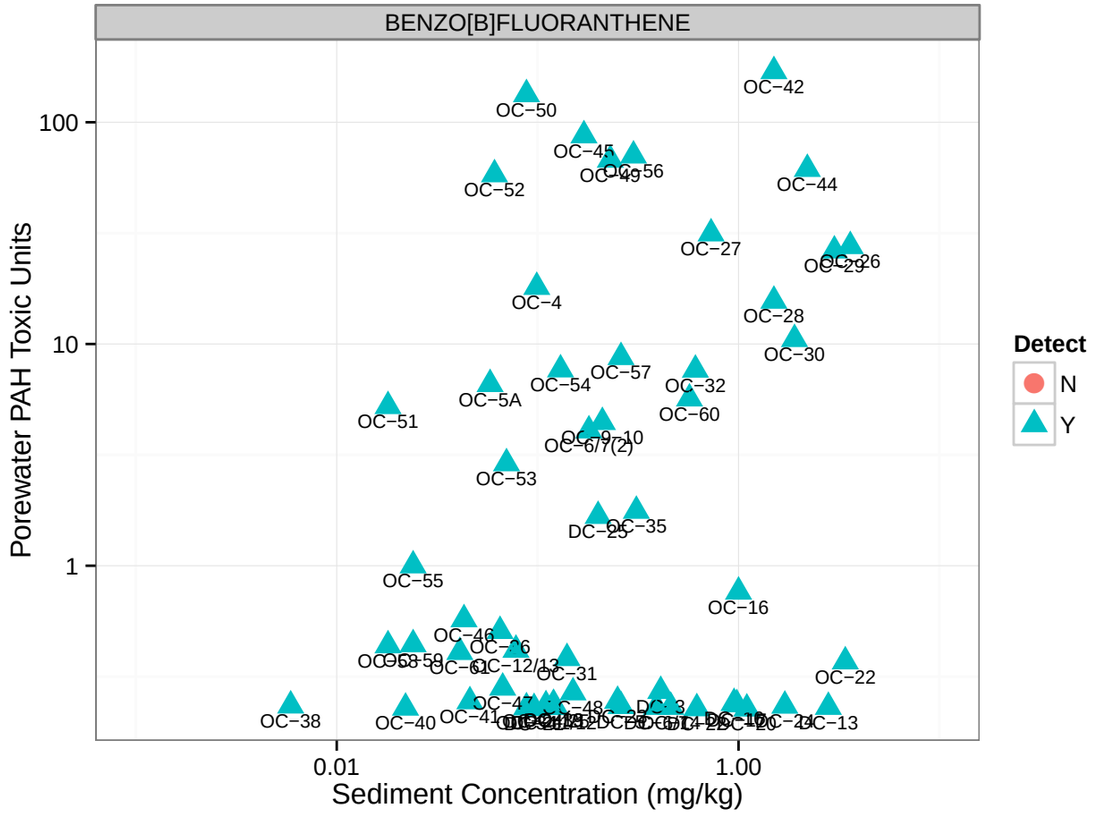
ACENAPHTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

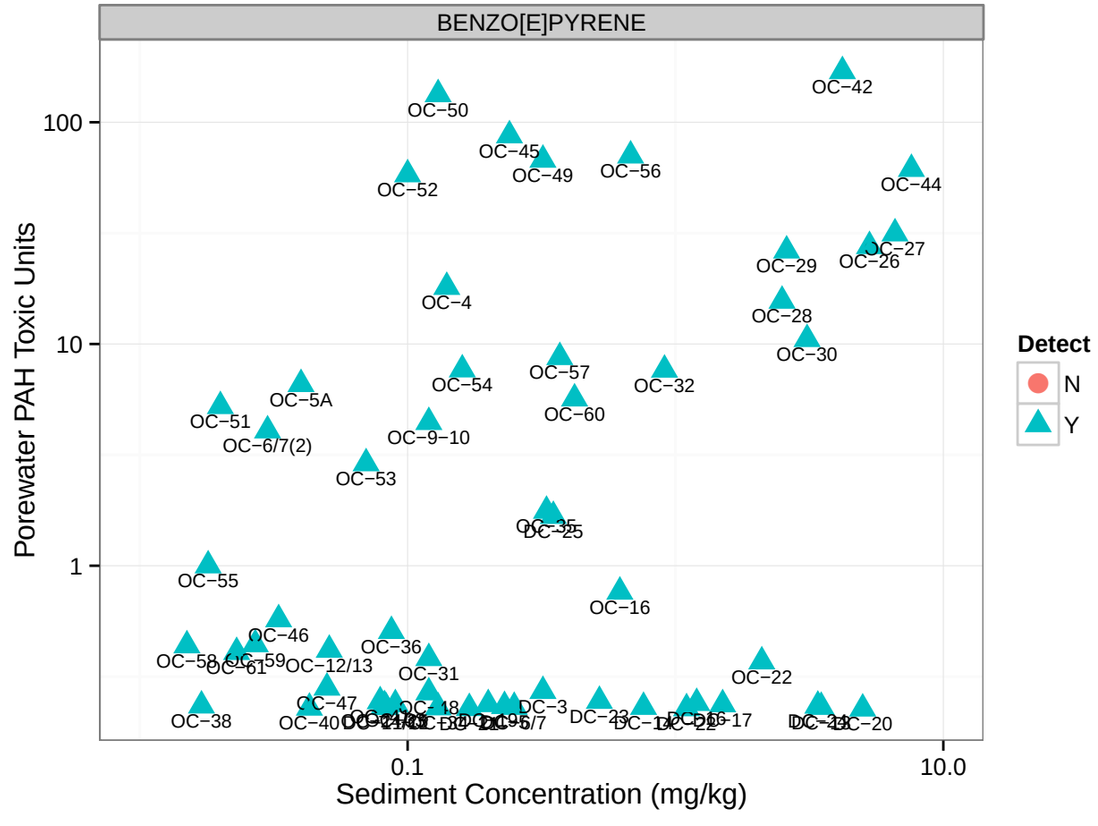

ACENAPHTHYLENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

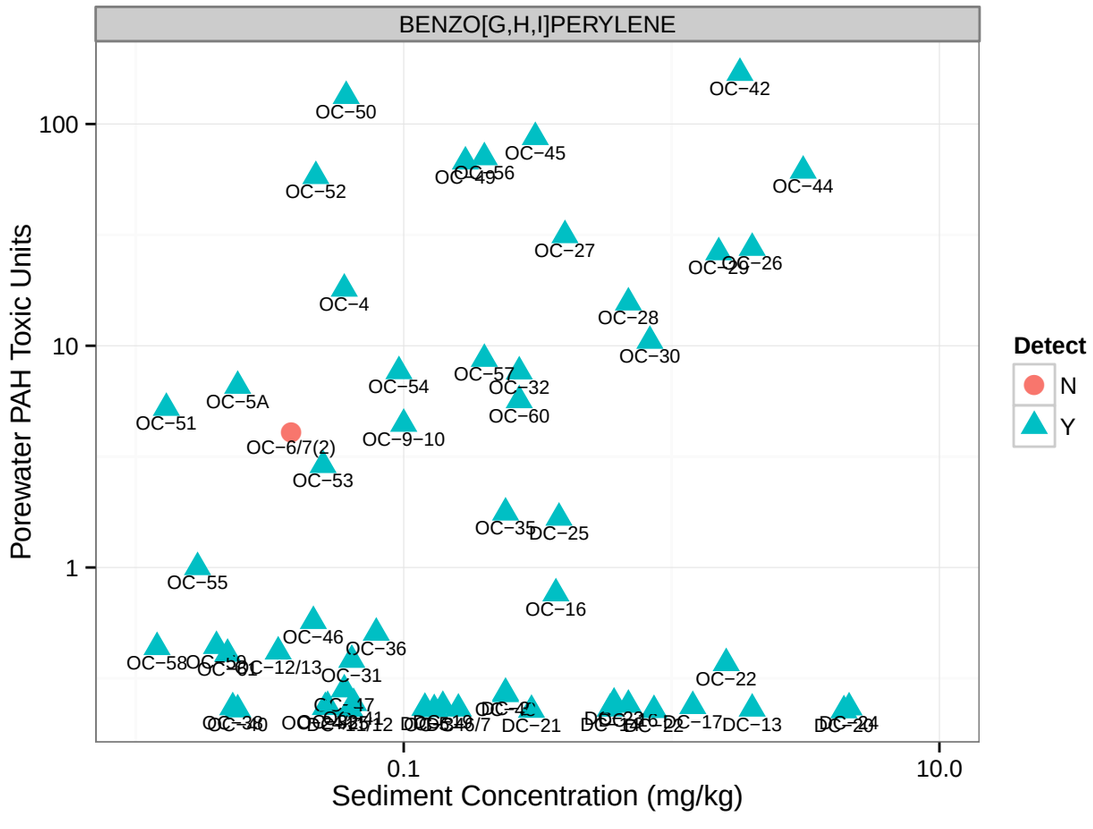

ANTHRACENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

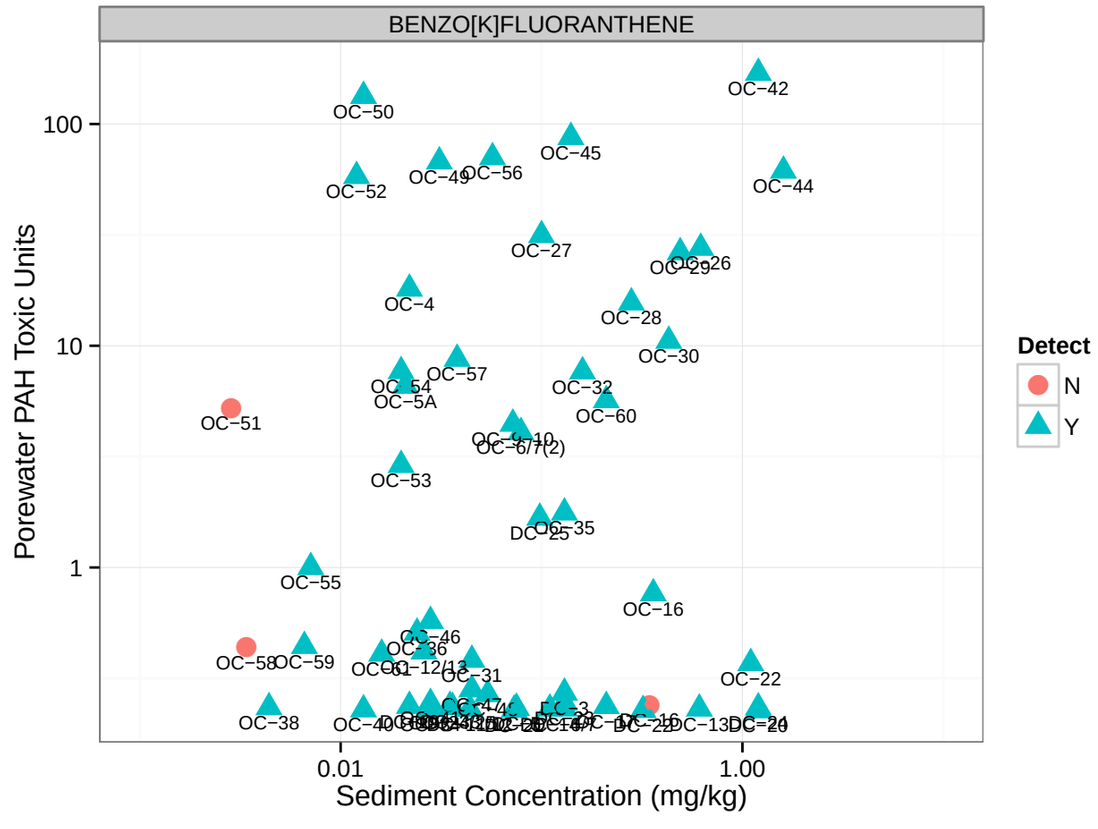

BENZO[A]ANTHRACENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

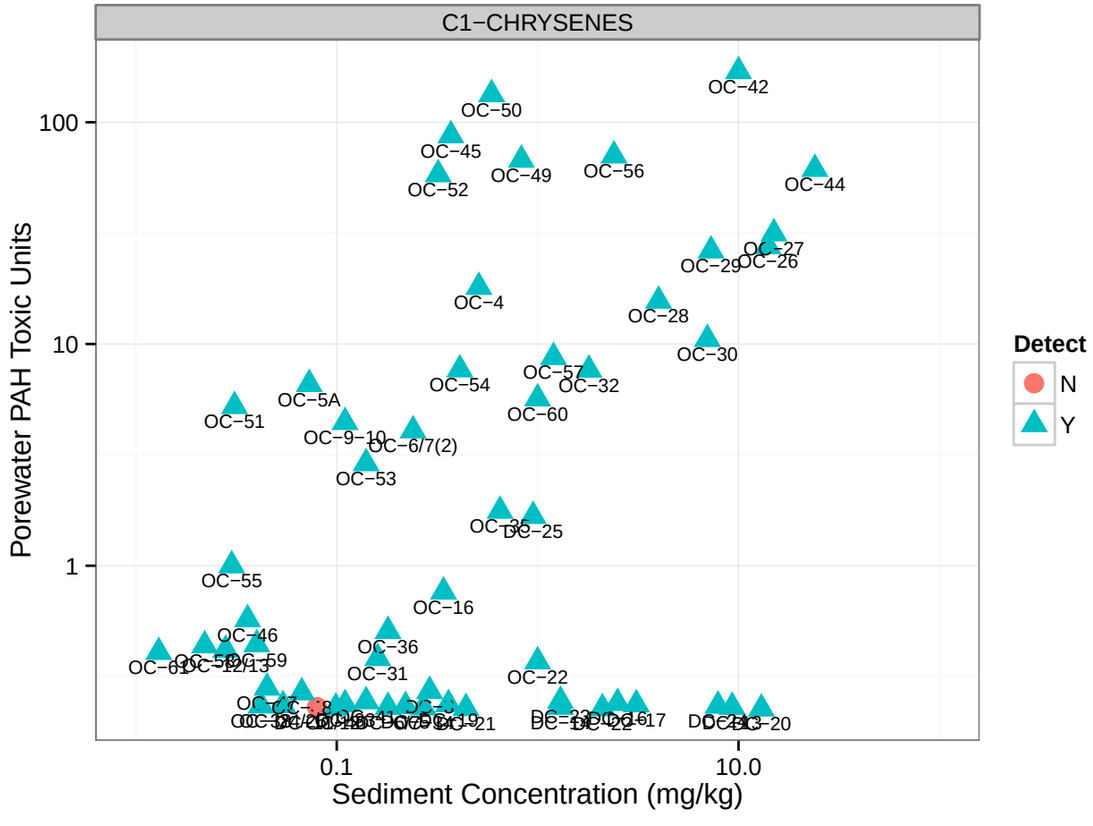

BENZO[A]PYRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

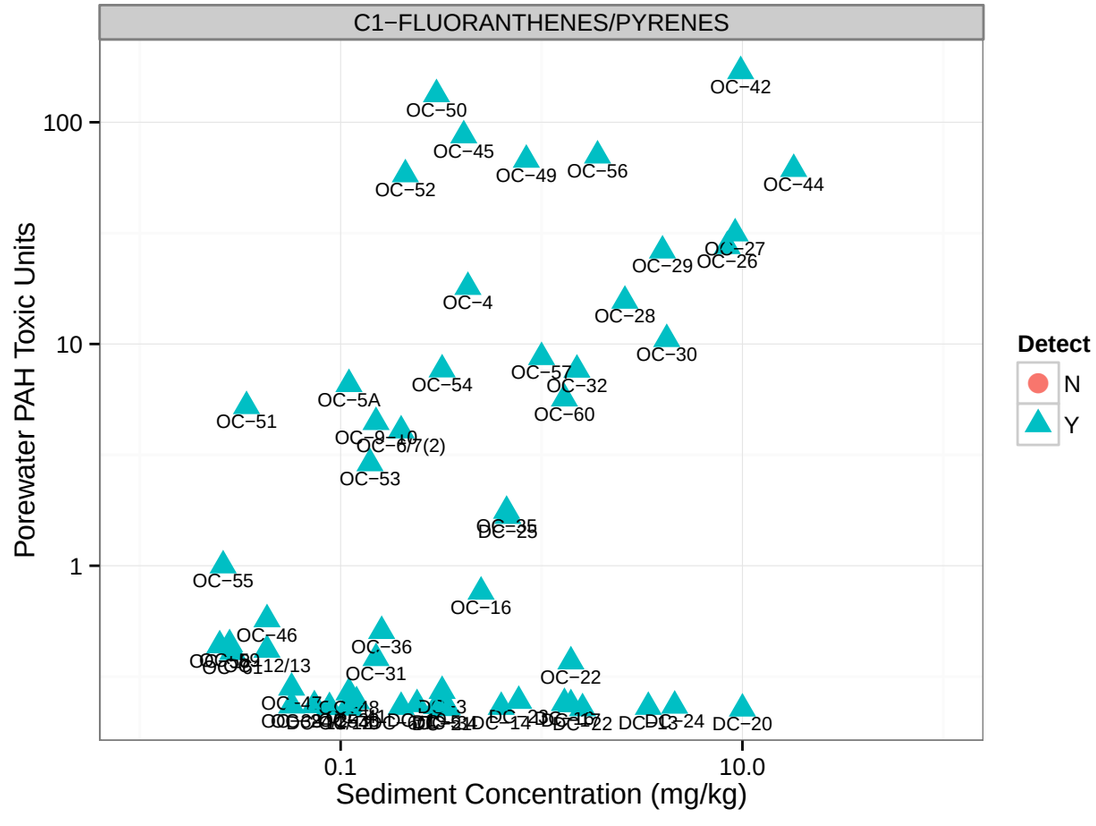

BENZO[B]FLUORANTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

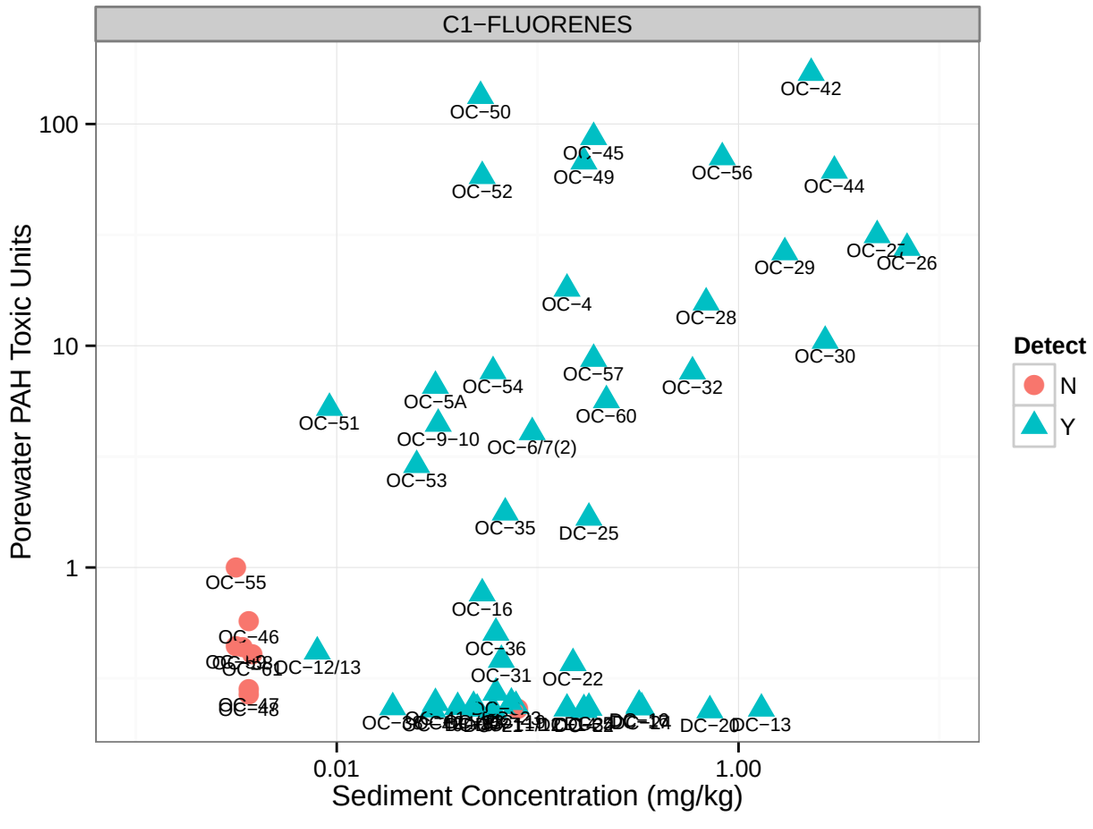

BENZO[E]PYRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

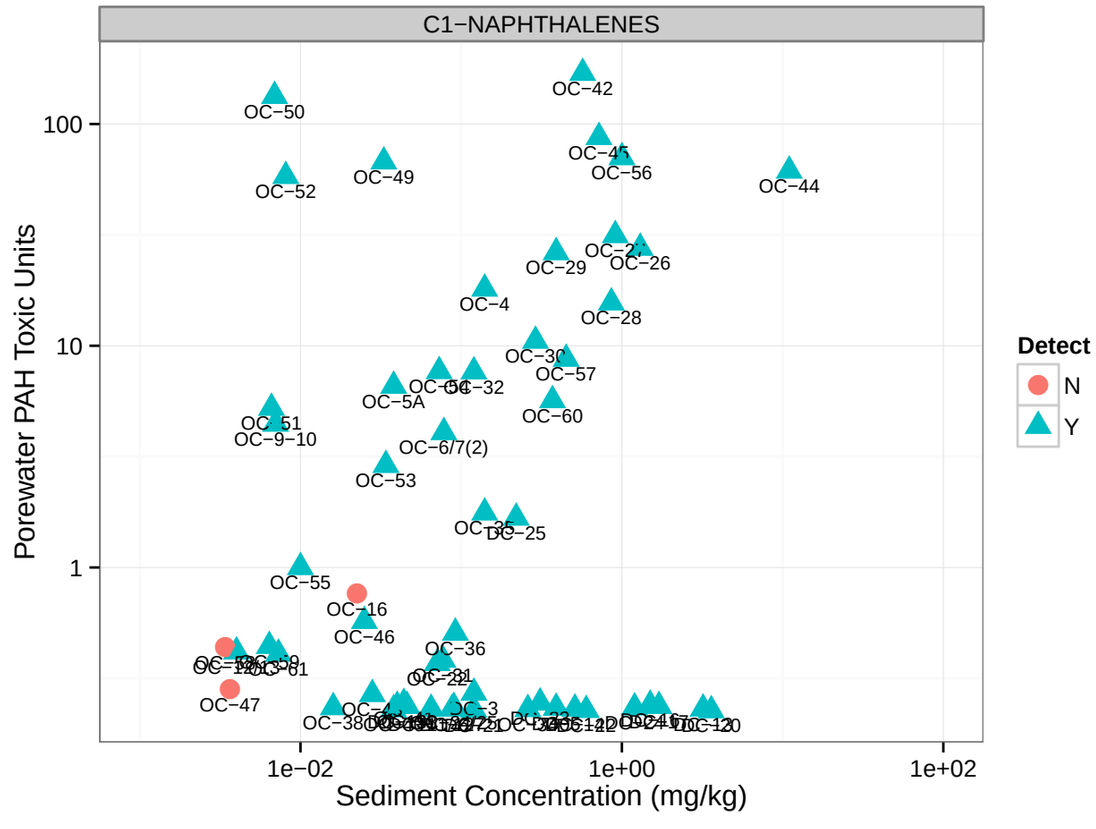

BENZO[G,H,I]PERYLENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

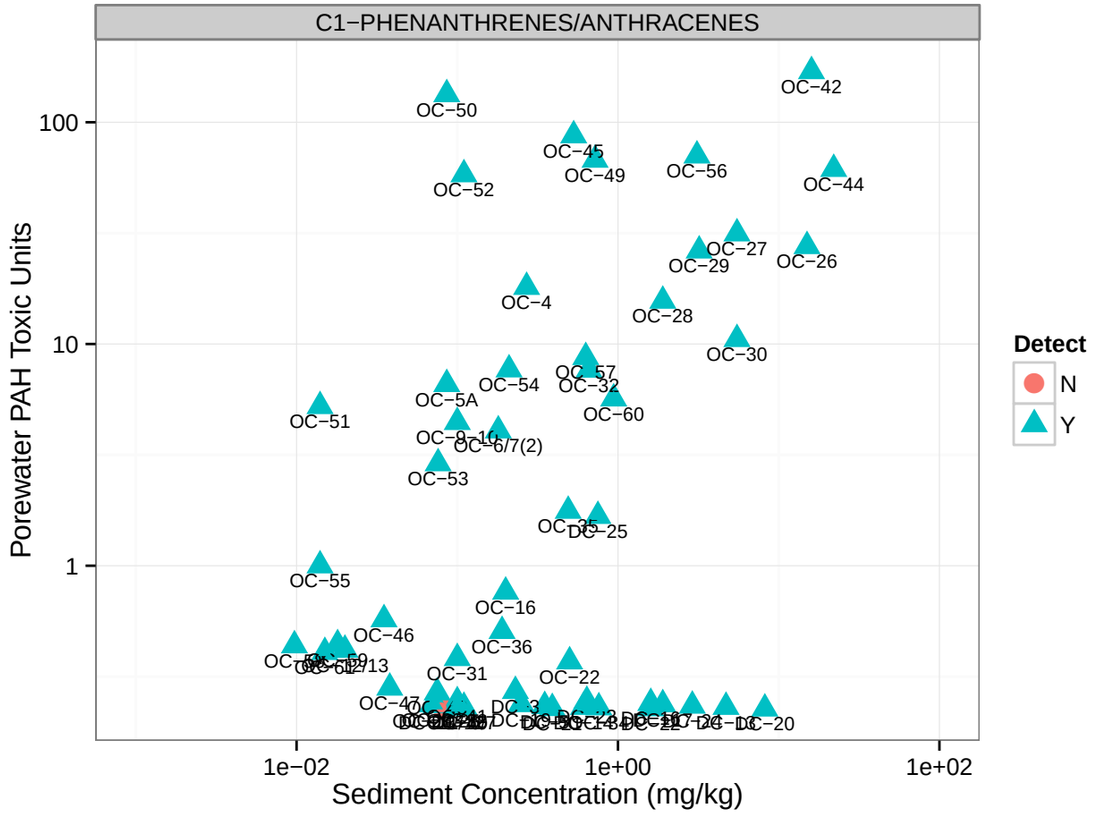

BENZO[K]FLUORANTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

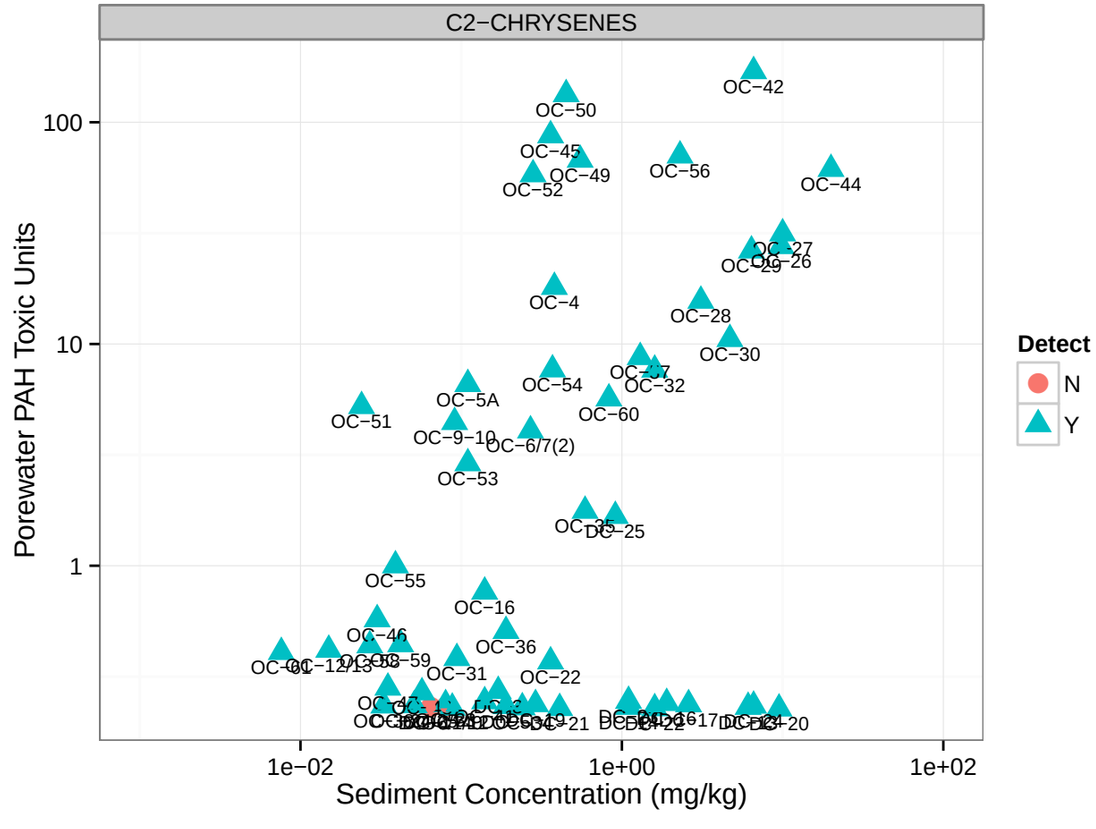

C1−CHRYSENES
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

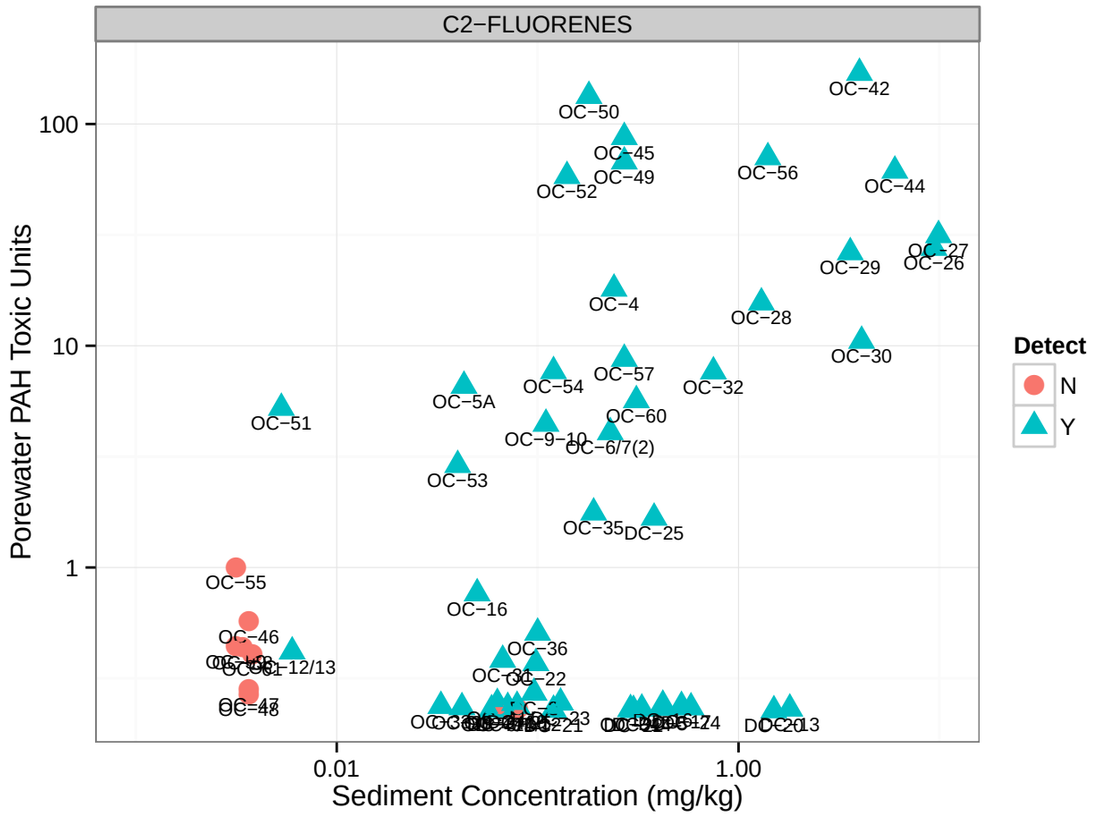

C1−FLUORANTHENES/PYRENES
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

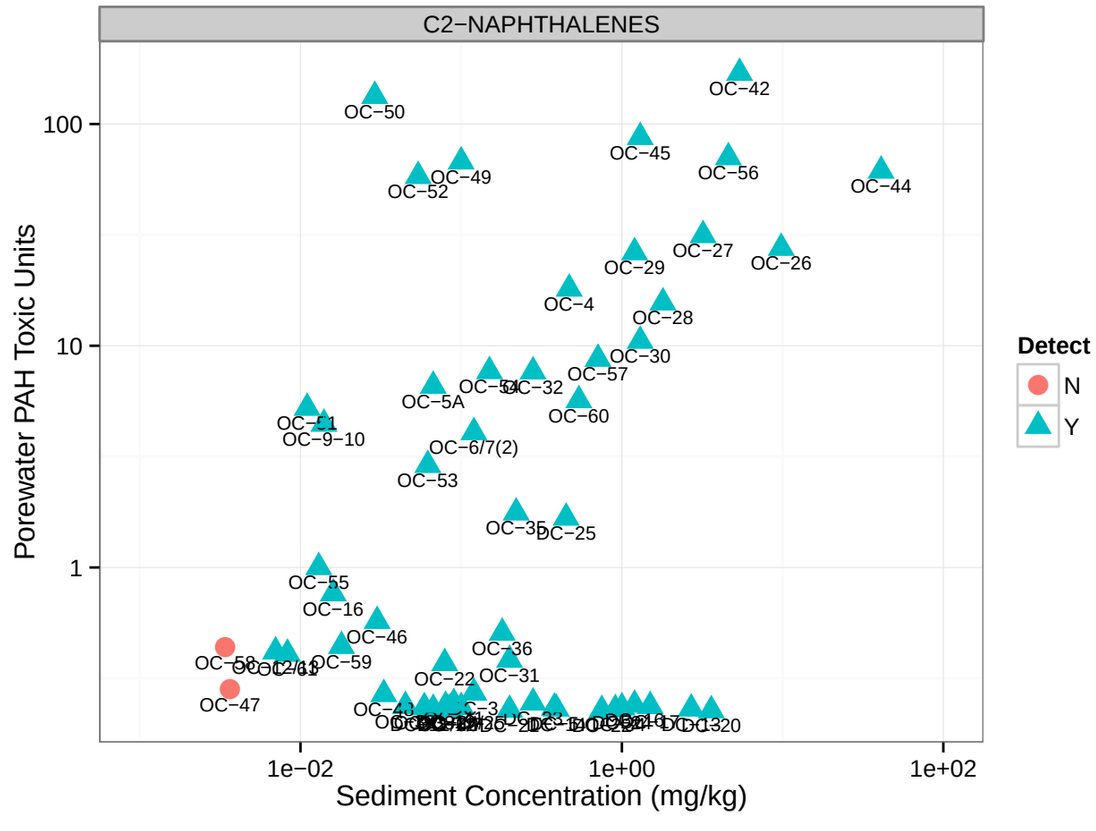

C1−FLUORENES
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

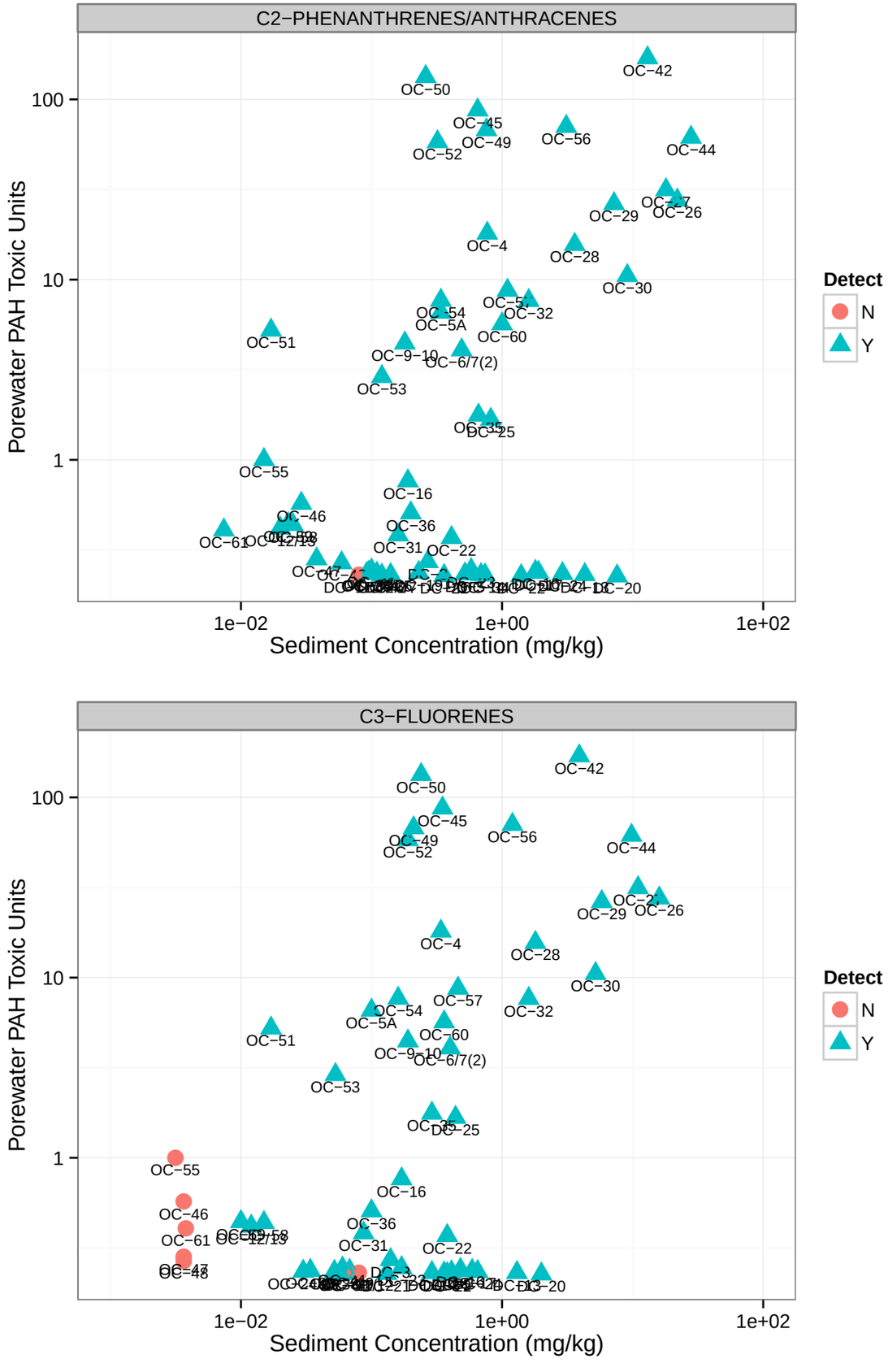

C1−NAPHTHALENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y

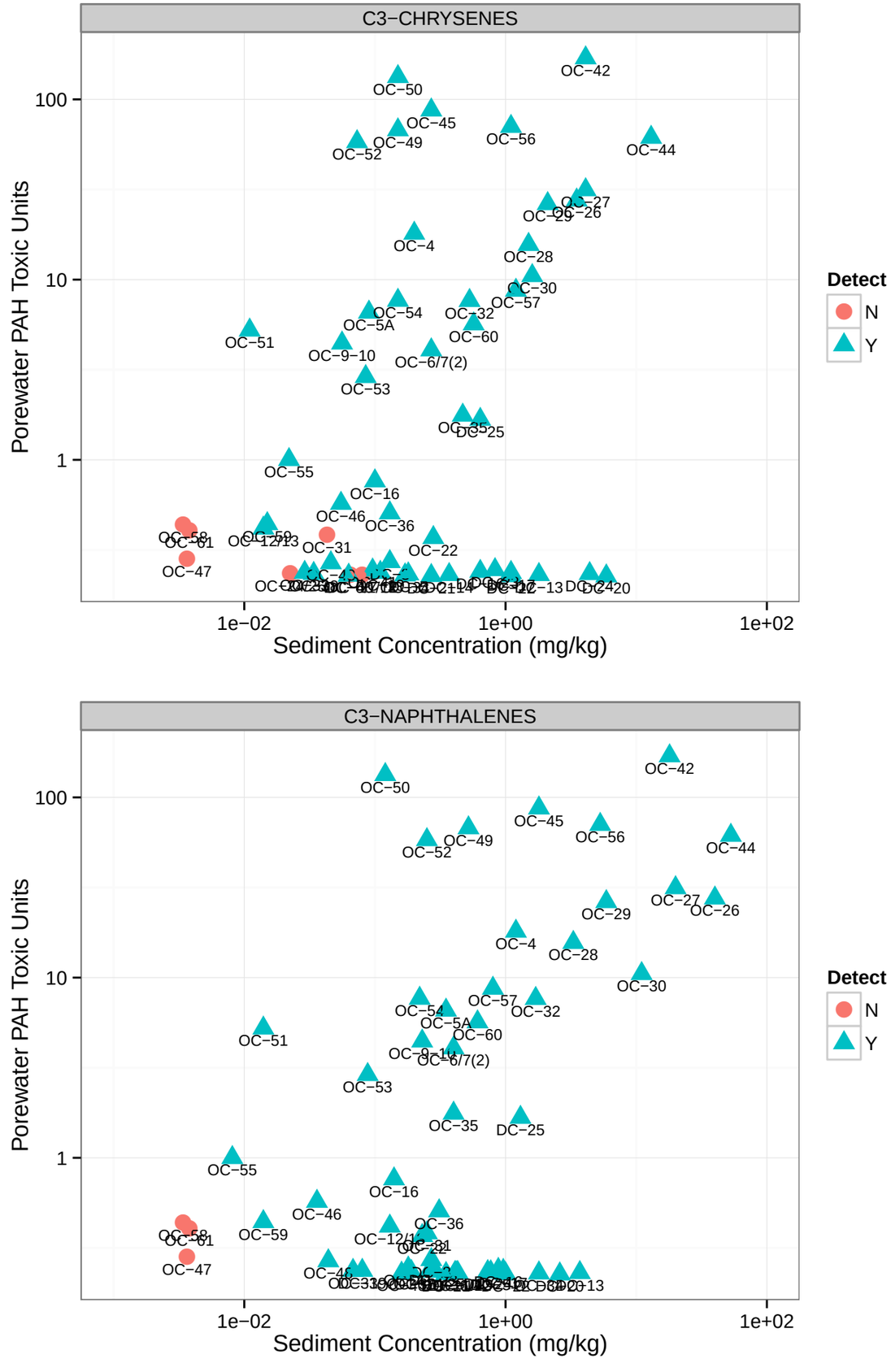

C1−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y


C2−CHRYSENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y


C2−FLUORENES
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

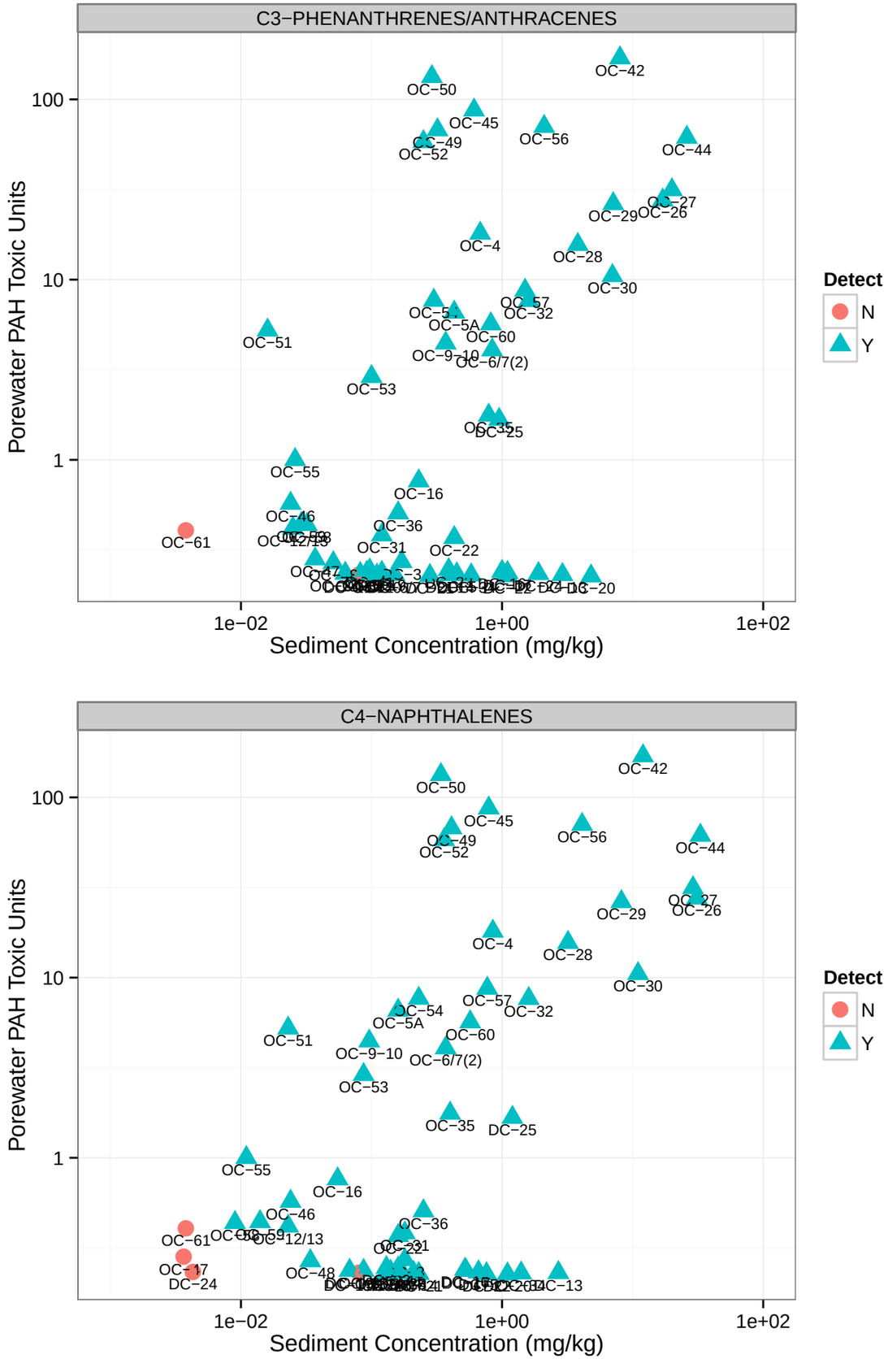

C2−NAPHTHALENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y

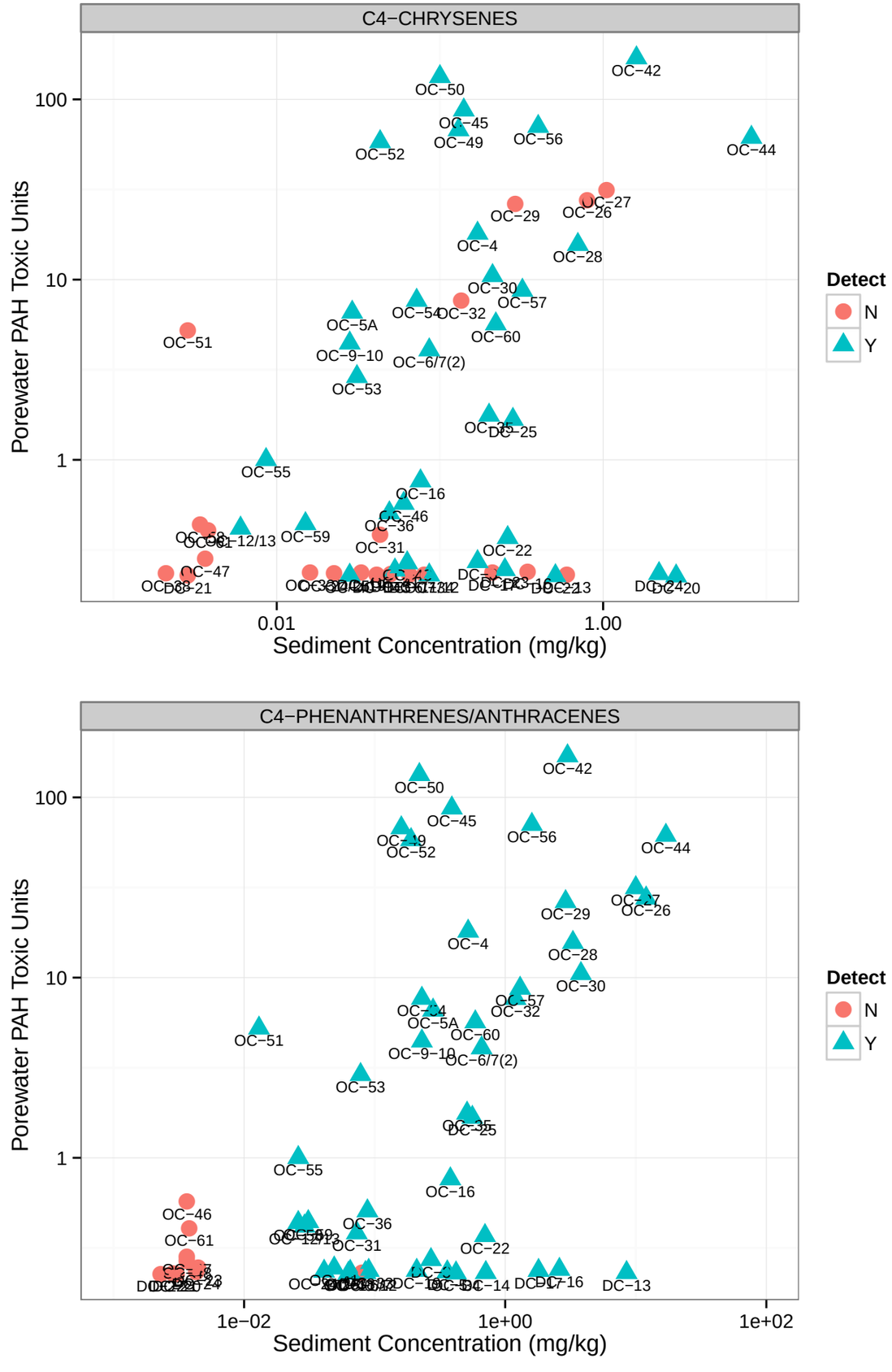

C2−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
100
10
1
1e−02
1e+00
1e+02
Detect
N
Y


C3−CHRYSENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
100
10
1
1e−02
1e+00
1e+02
Detect
N
Y

C3−FLUORENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
100
10
1
1e−02
1e+00
1e+02
Detect
N
Y

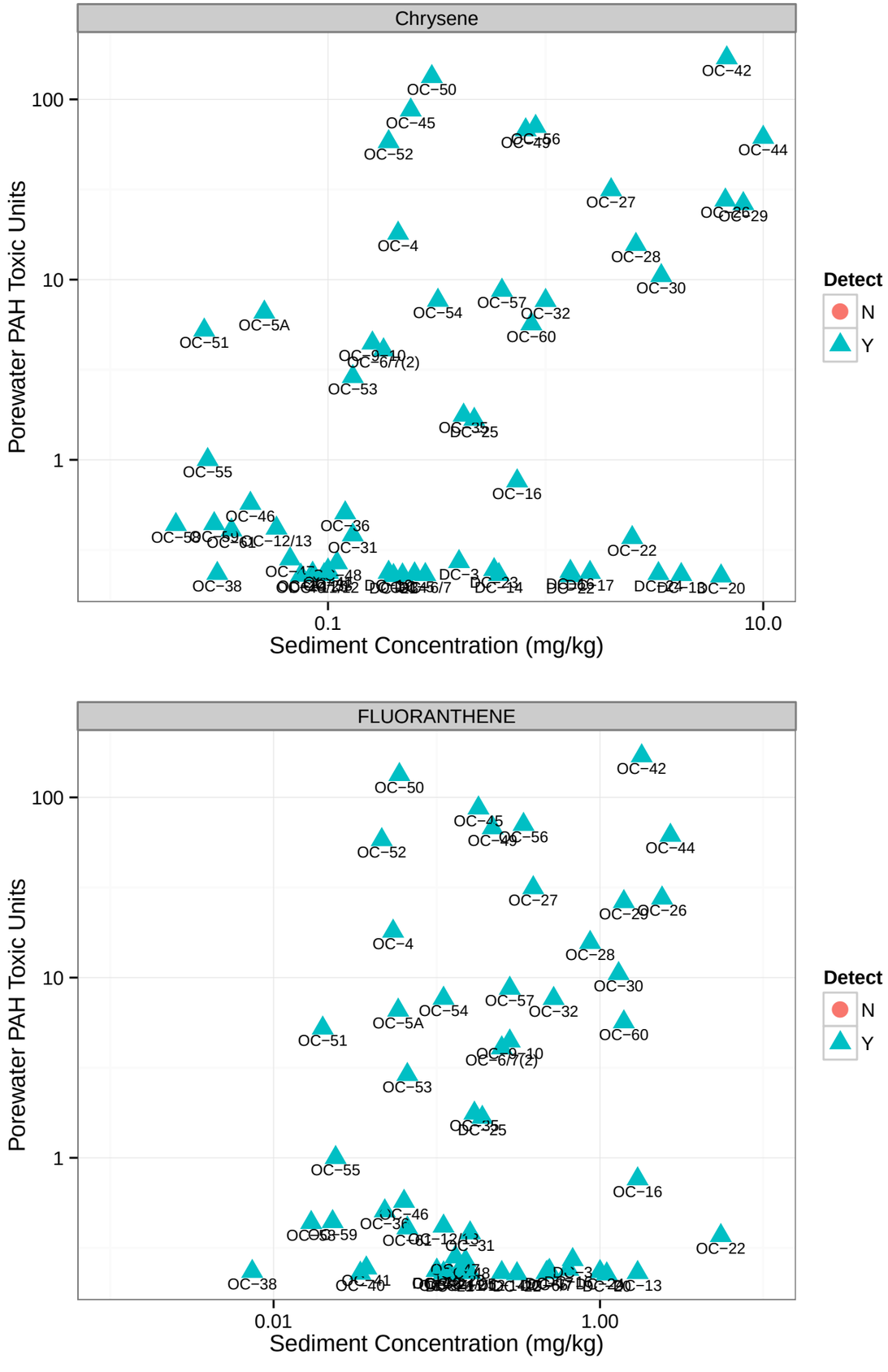
C3−NAPHTHALENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
100
10
1
1e−02
1e+00
1e+02
Detect
N
Y

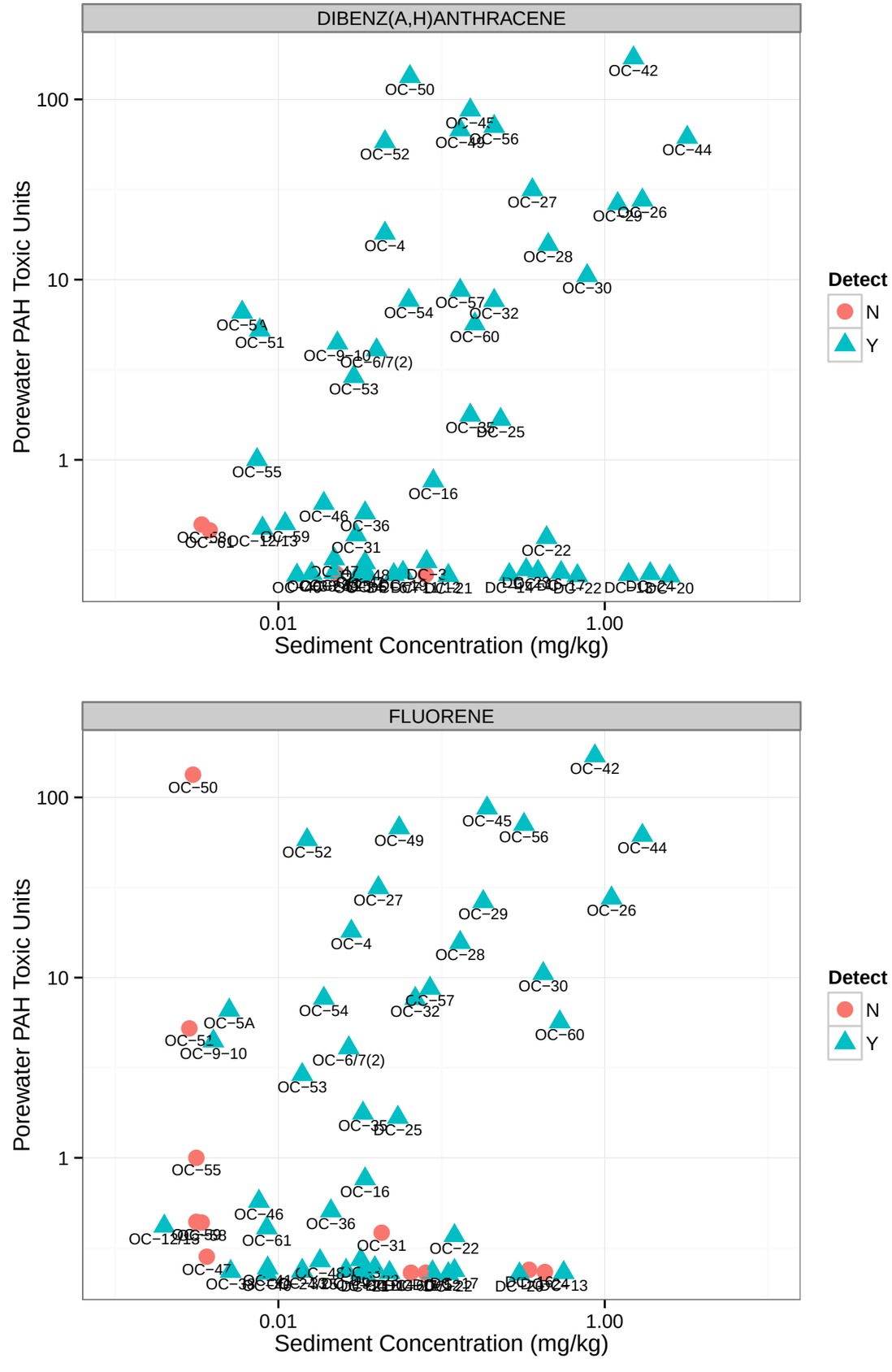

C3−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
Detect
N
Y


C4−CHRYSENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
Detect
N
Y

C4−NAPHTHALENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
Detect
N
Y

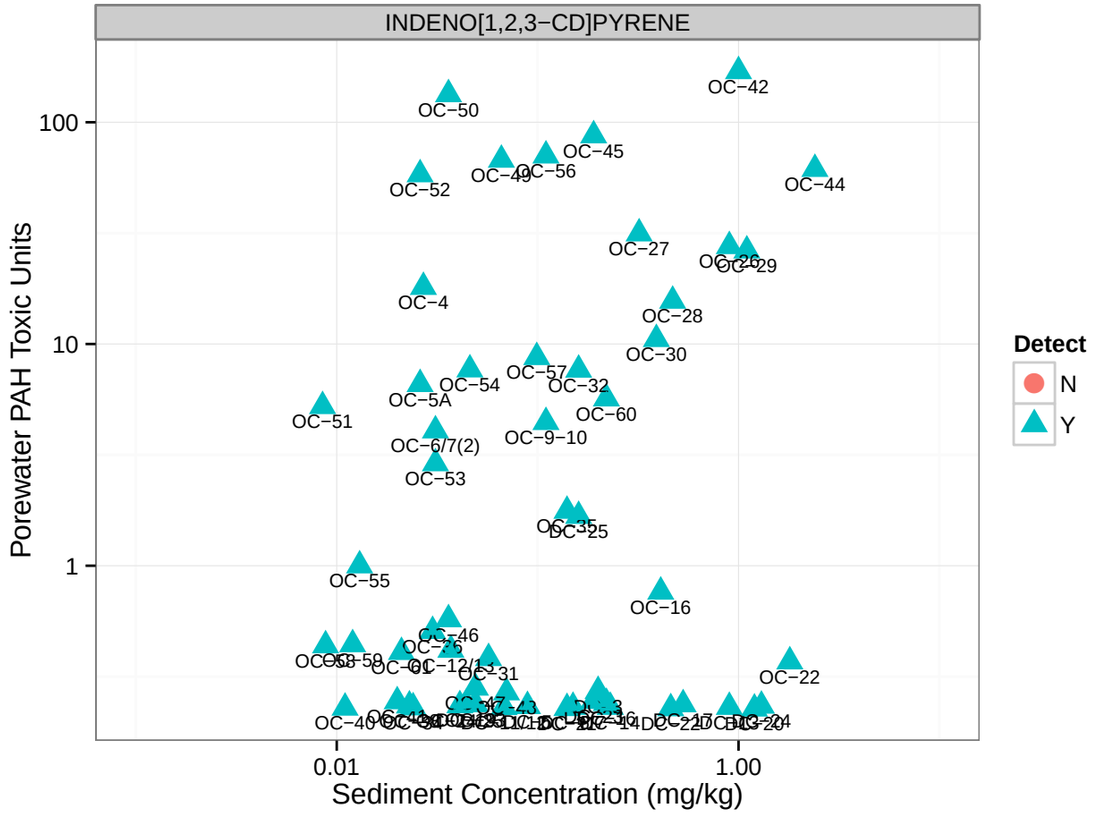
C4−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
Sediment Concentration (mg/kg)
Detect
N
Y

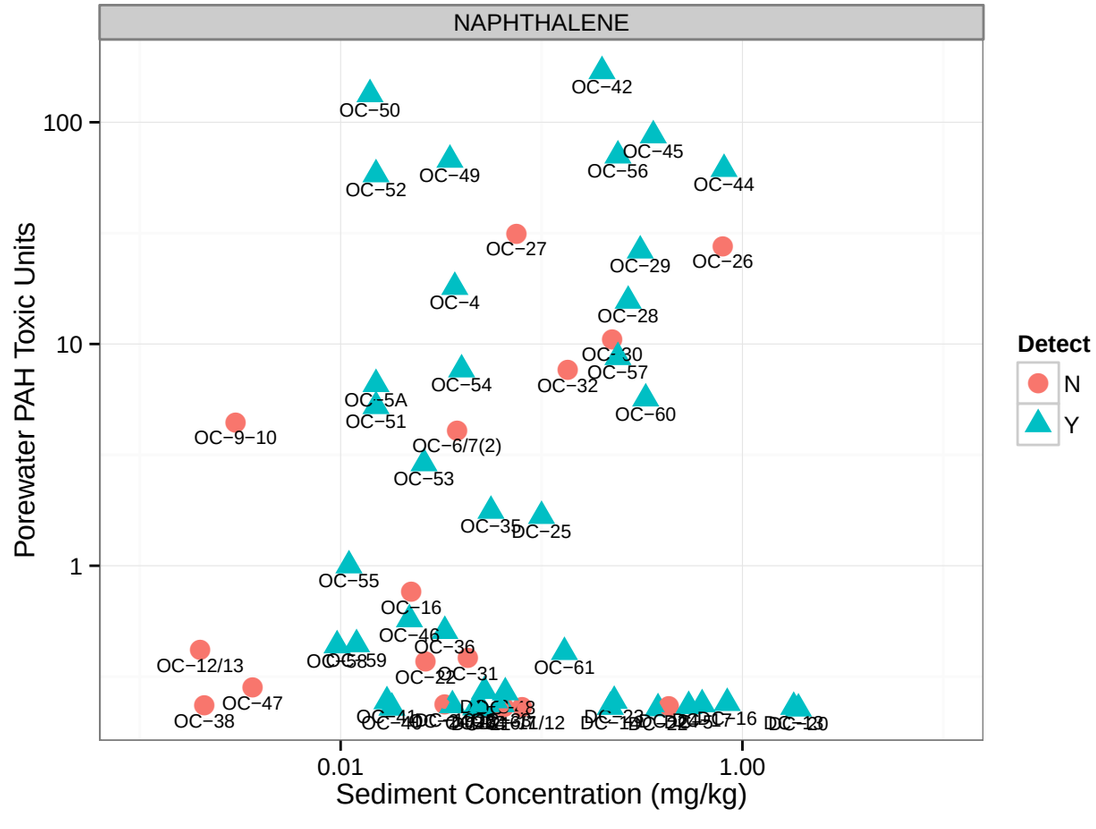

Chrysene
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

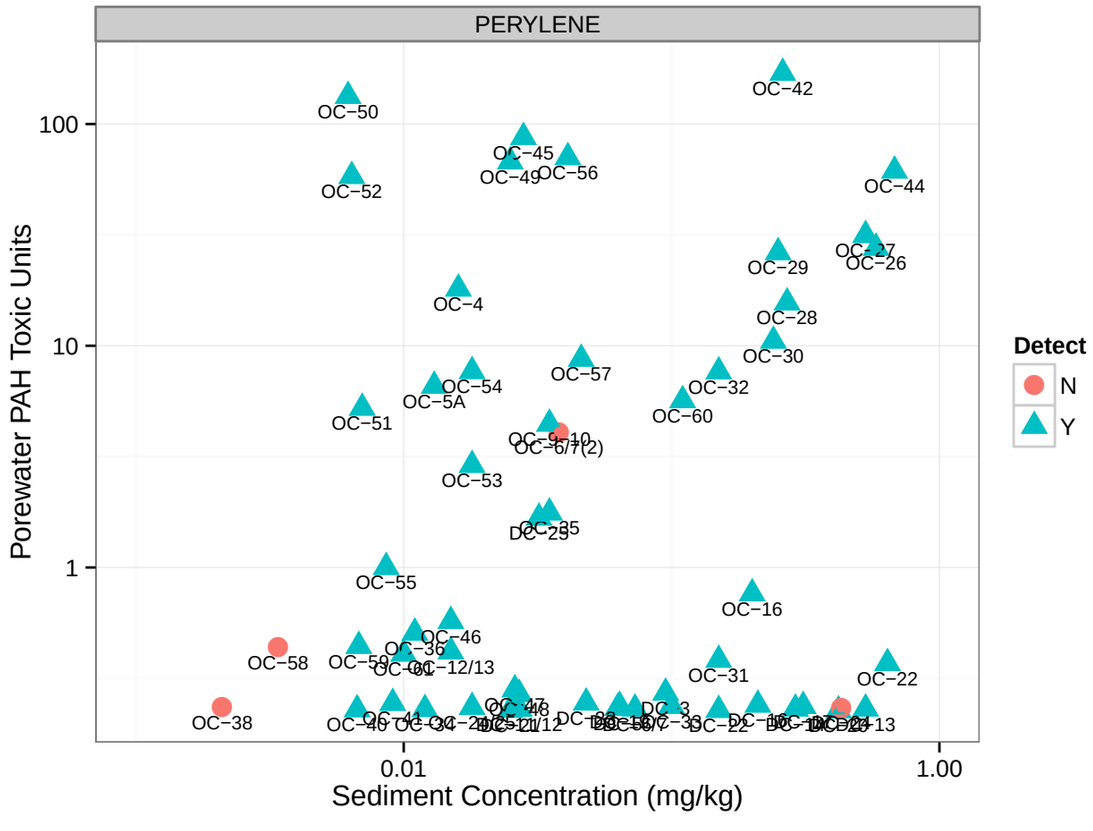

DIBENZ(A,H)ANTHRACENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

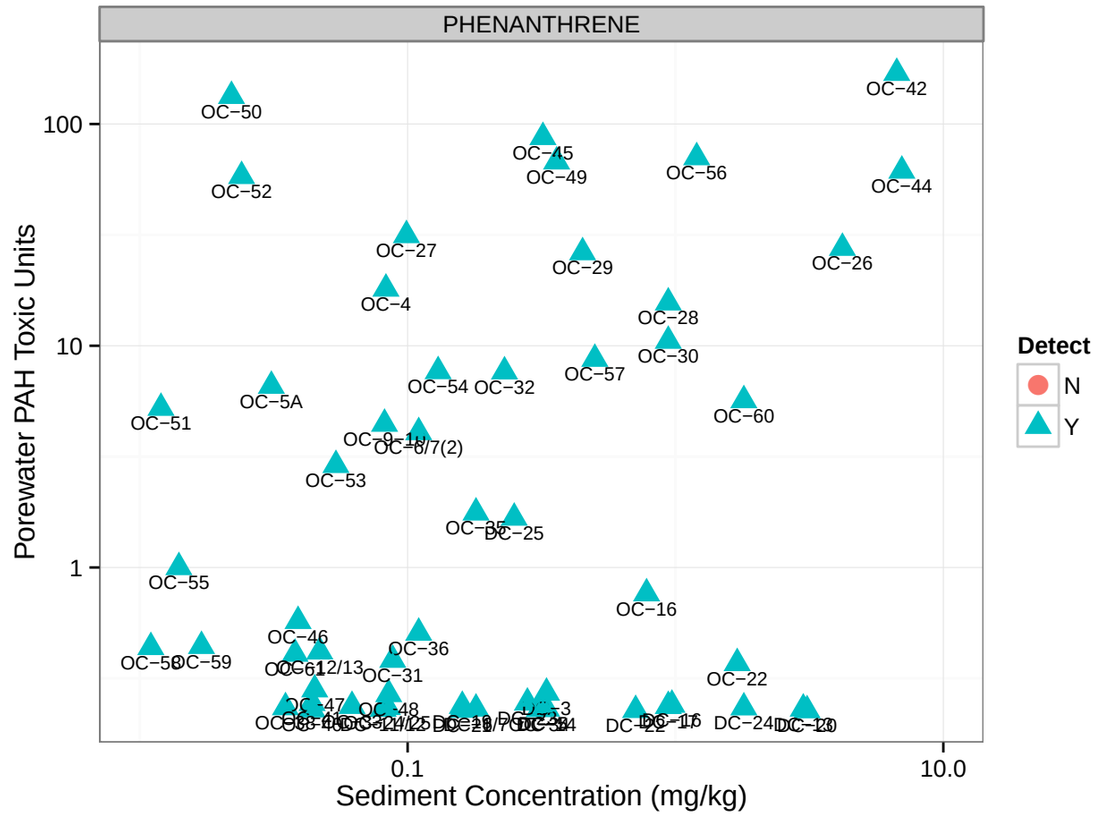
FLUORANTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

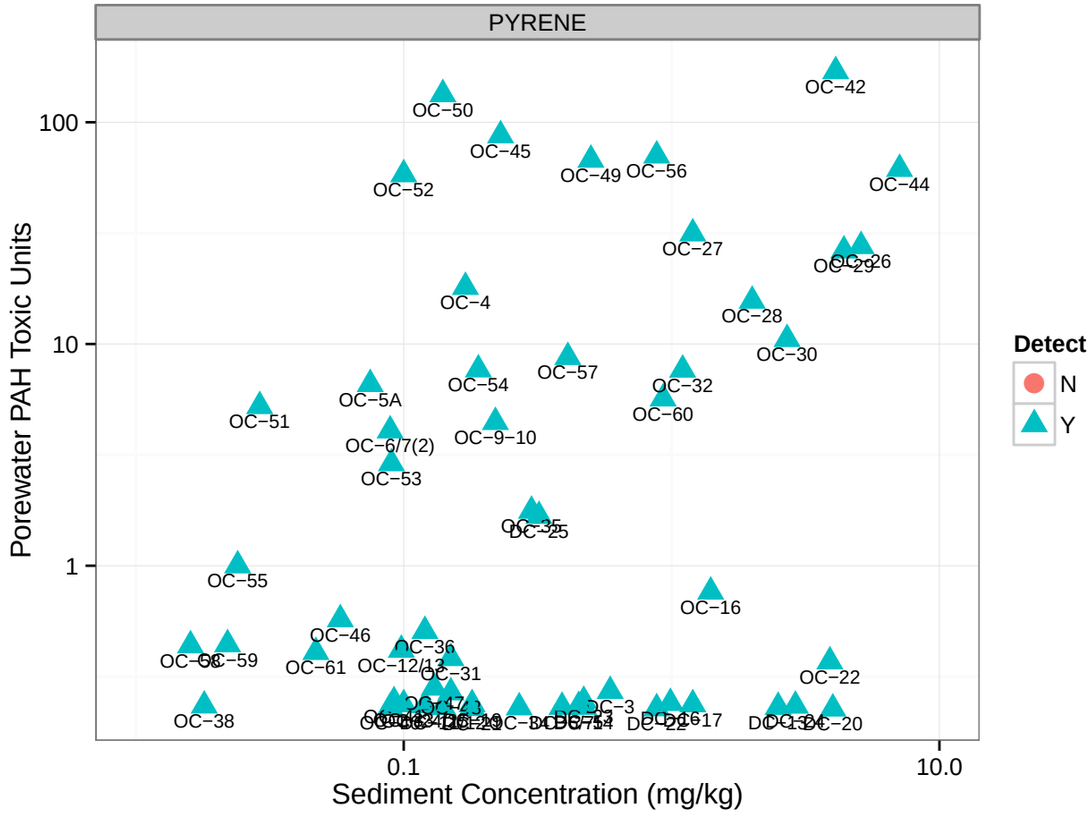
FLUORENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

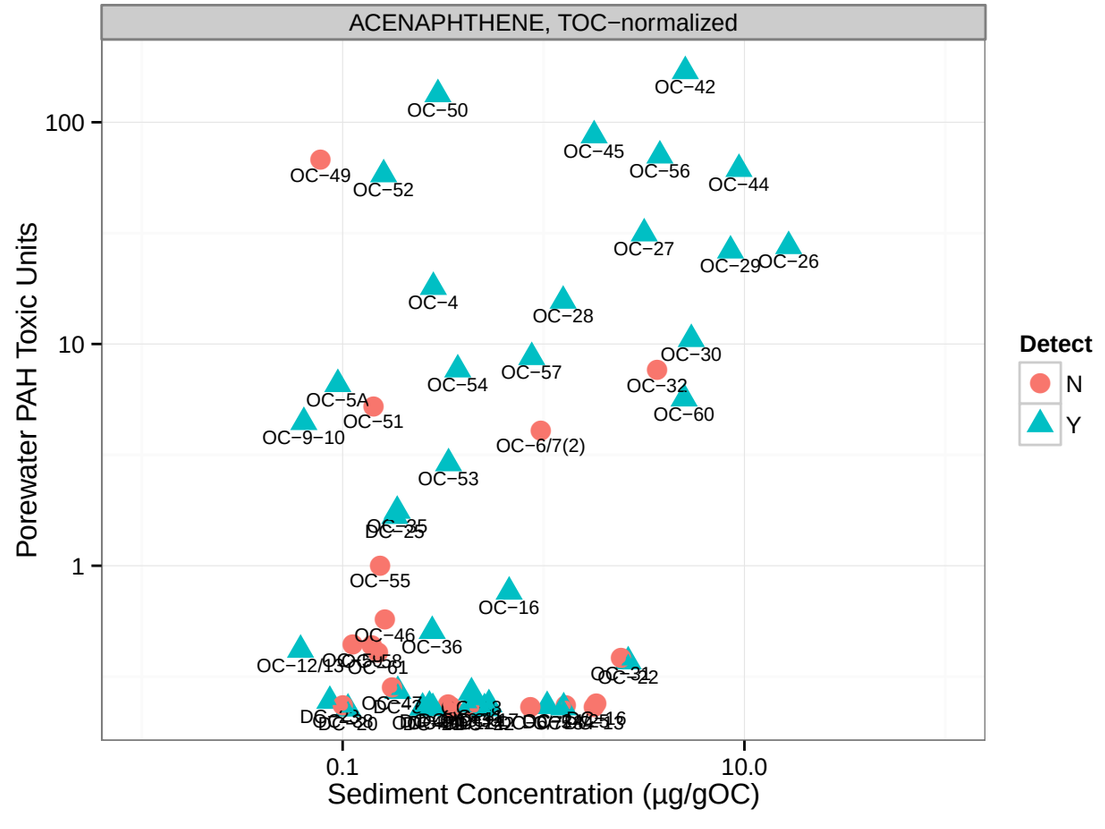

INDENO[1,2,3−CD]PYRENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

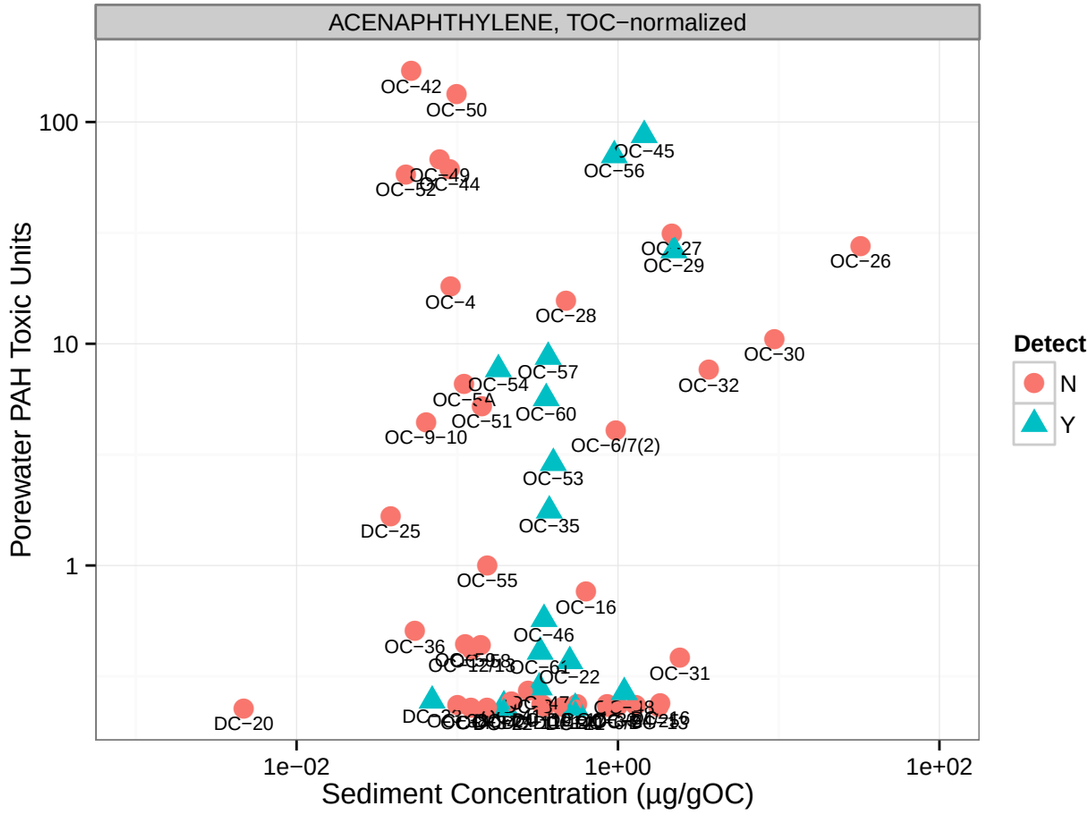

NAPHTHALENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

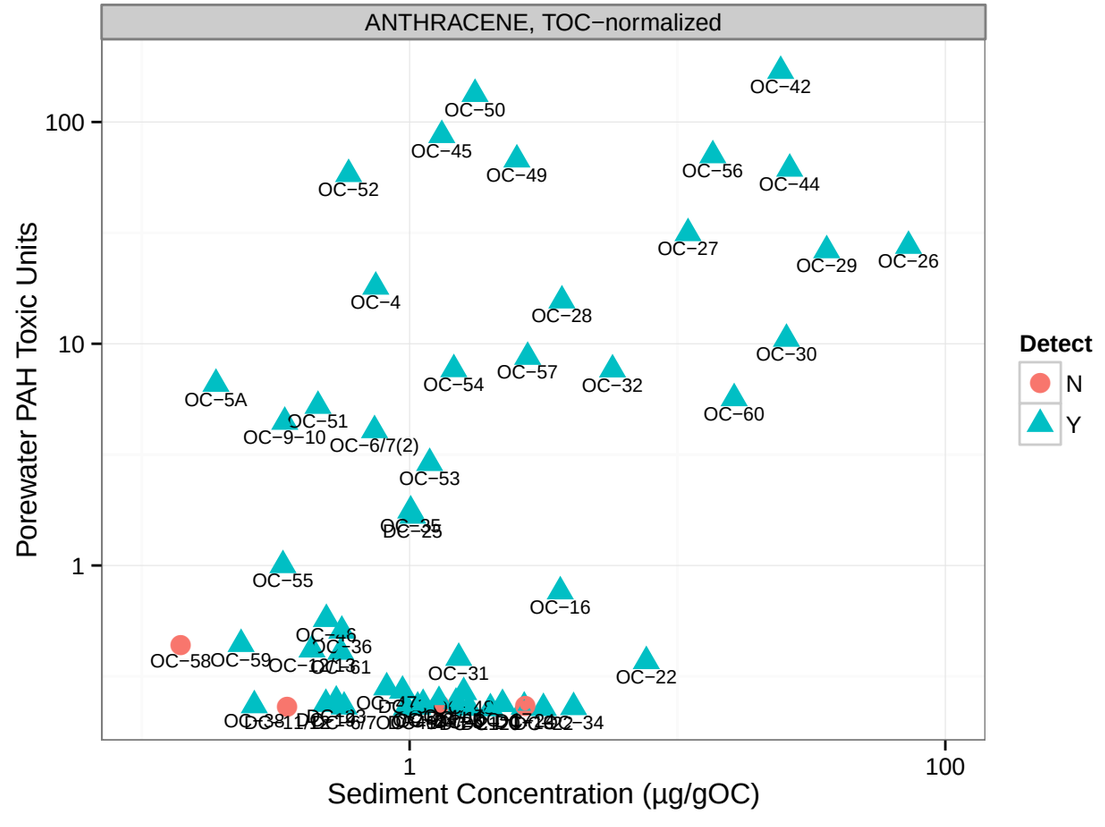

PERYLENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
Detect
N
Y

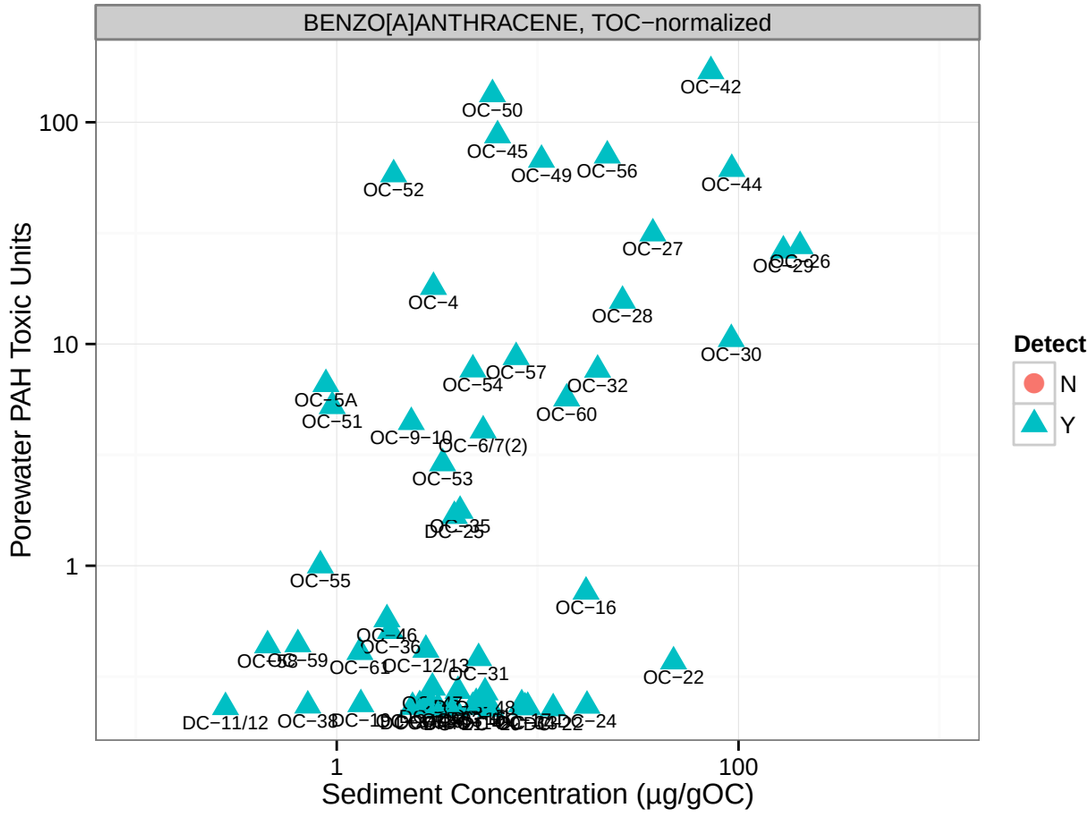

PHENANTHRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
Detect
N
Y

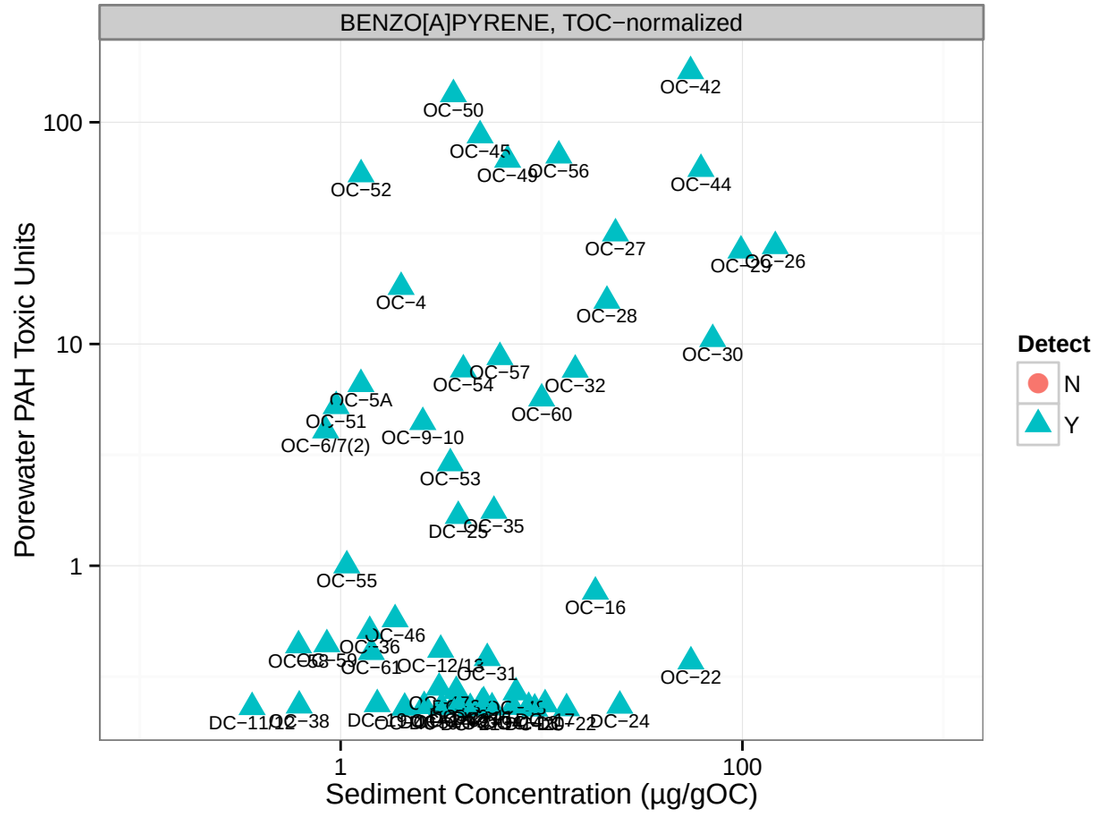

PYRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
DC−25
OC−55
OC−16
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−22
OC−38
DC−20
Detect
N
Y

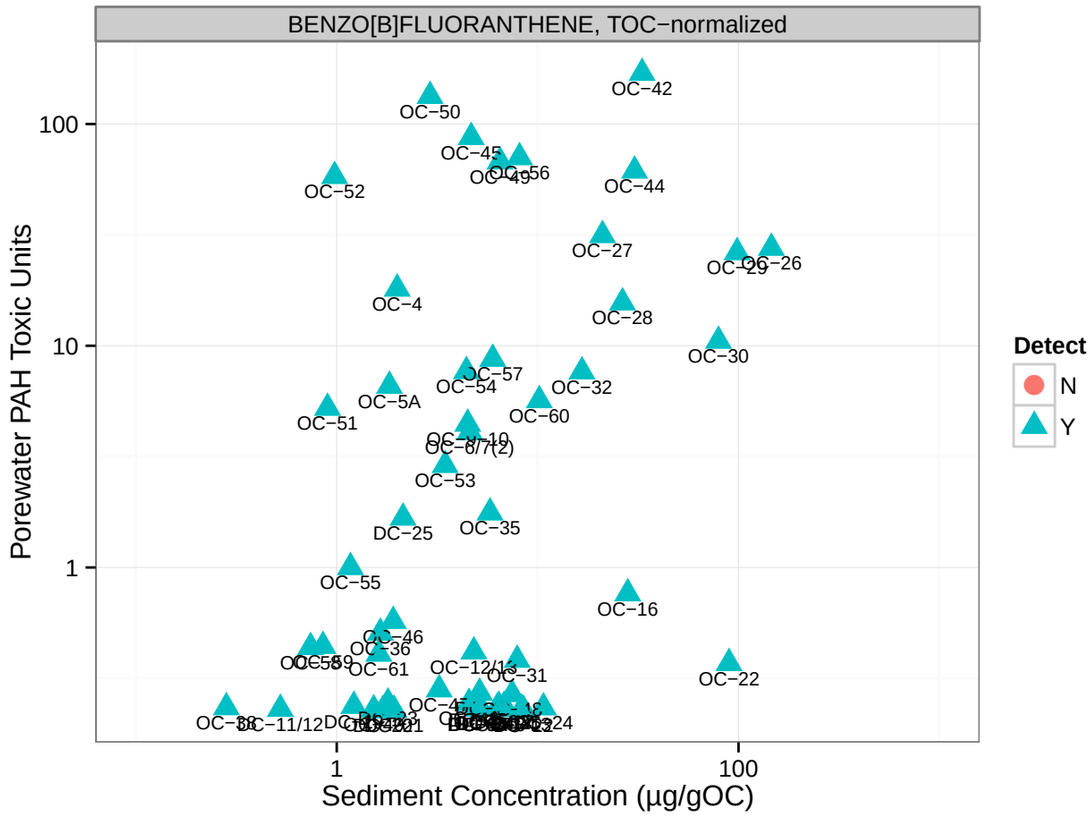

ACENAPHTHENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
DC−25
OC−55
OC−16
OC−46
OC−36
OC−12/13
OC−61
OC−31
OC−22
Detect
N
Y

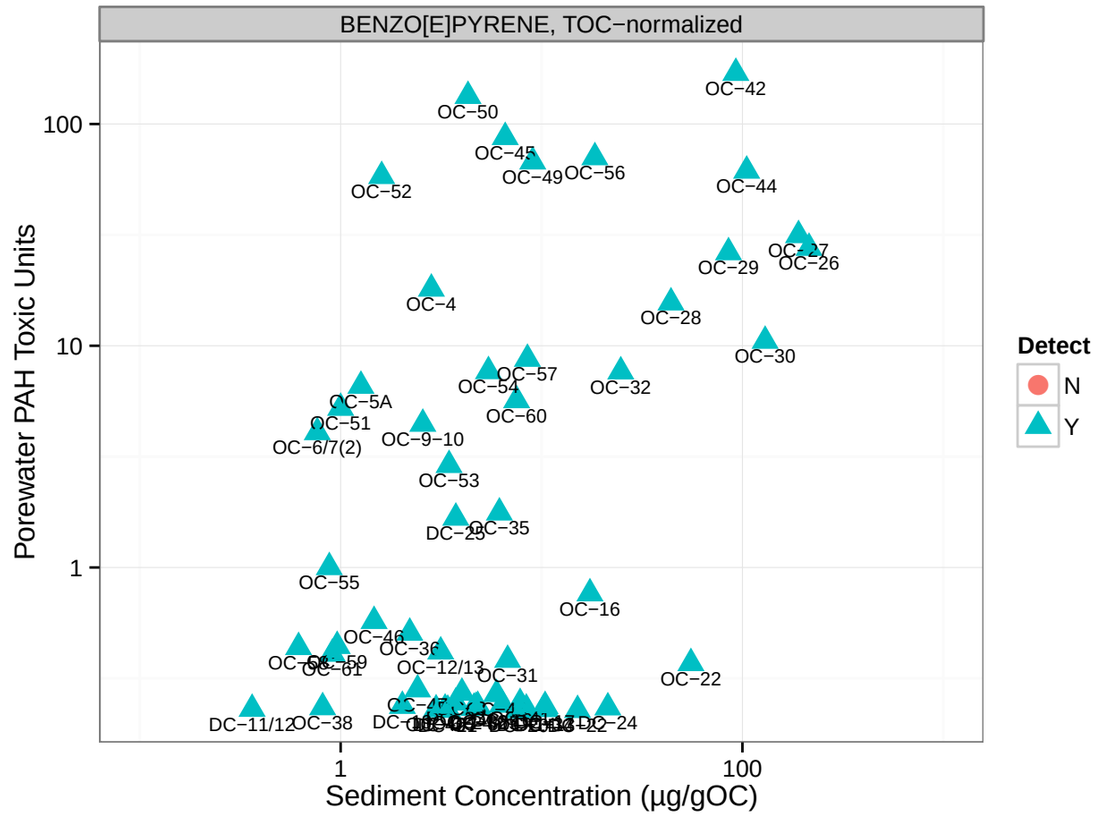

ACENAPHTHYLENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−54
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
DC−25
OC−35
OC−55
OC−16
OC−46
OC−36
OC−61
OC−22
OC−31
DC−20
Detect
N
Y

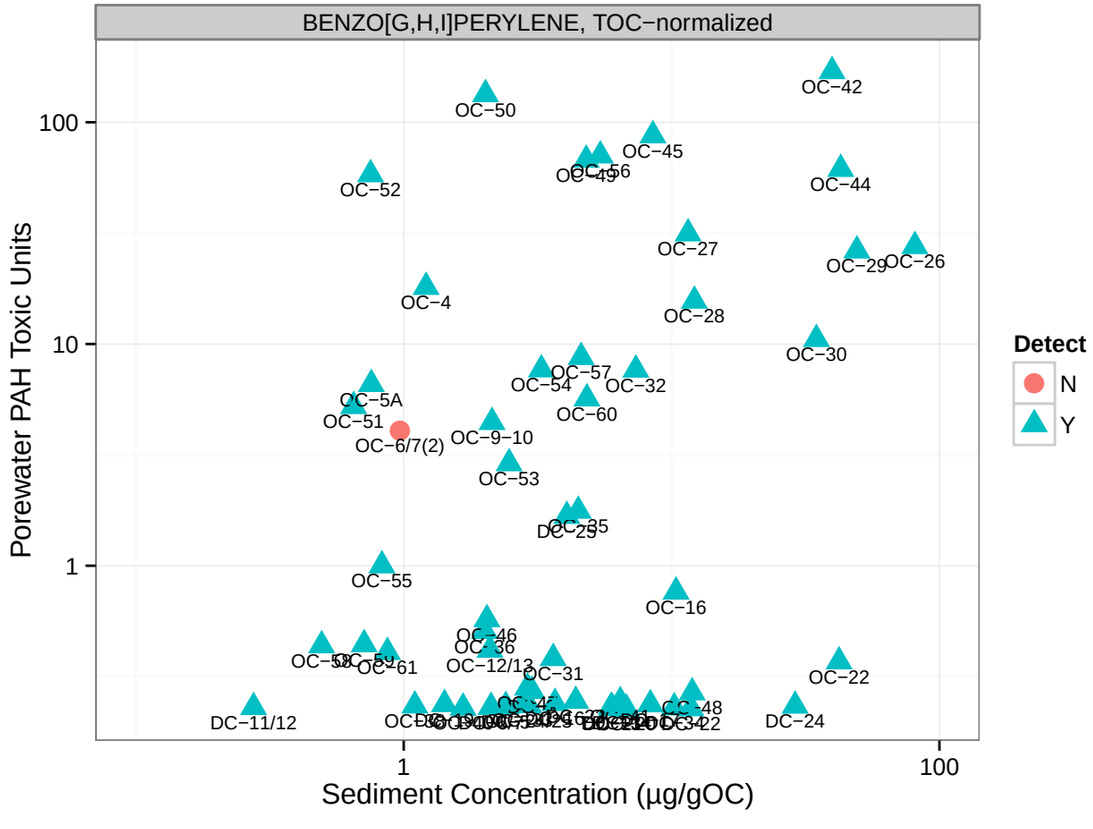

ANTHRACENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
DC−25
OC−55
OC−16
OC−46
OC−36
OC−58
OC−59
OC−22
OC−31
Detect
N
Y

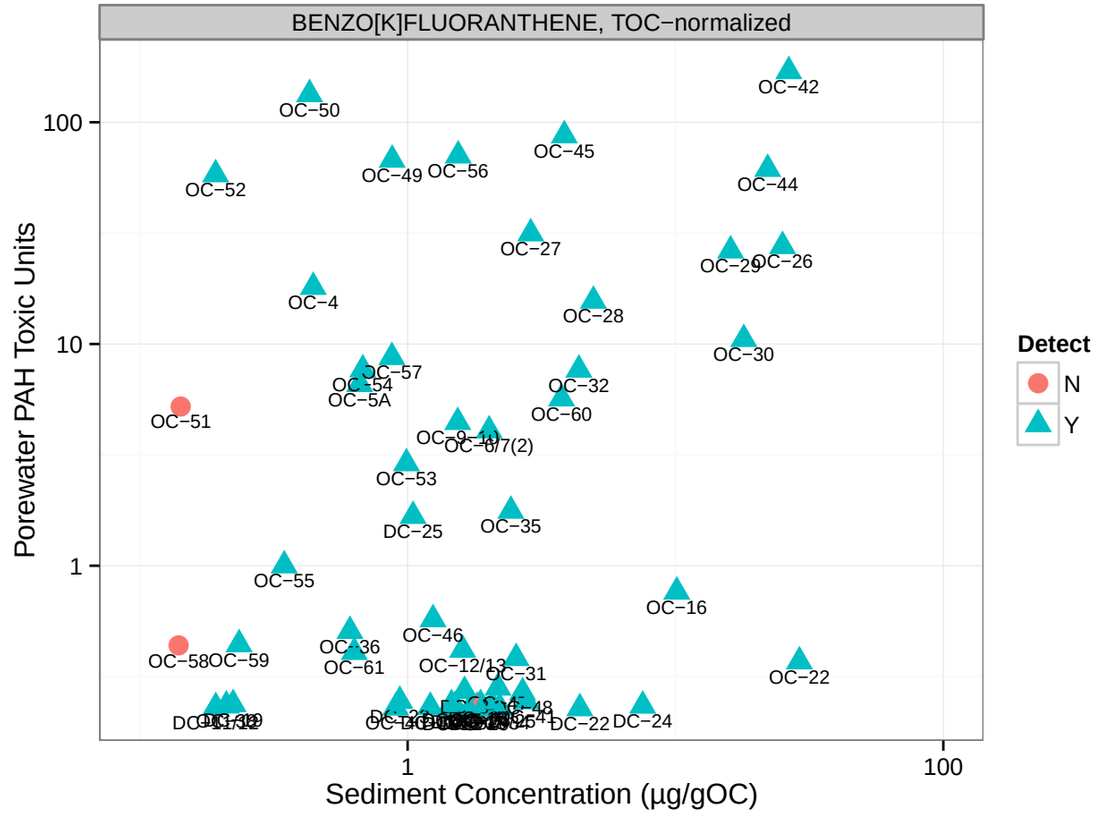

BENZO[A]ANTHRACENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

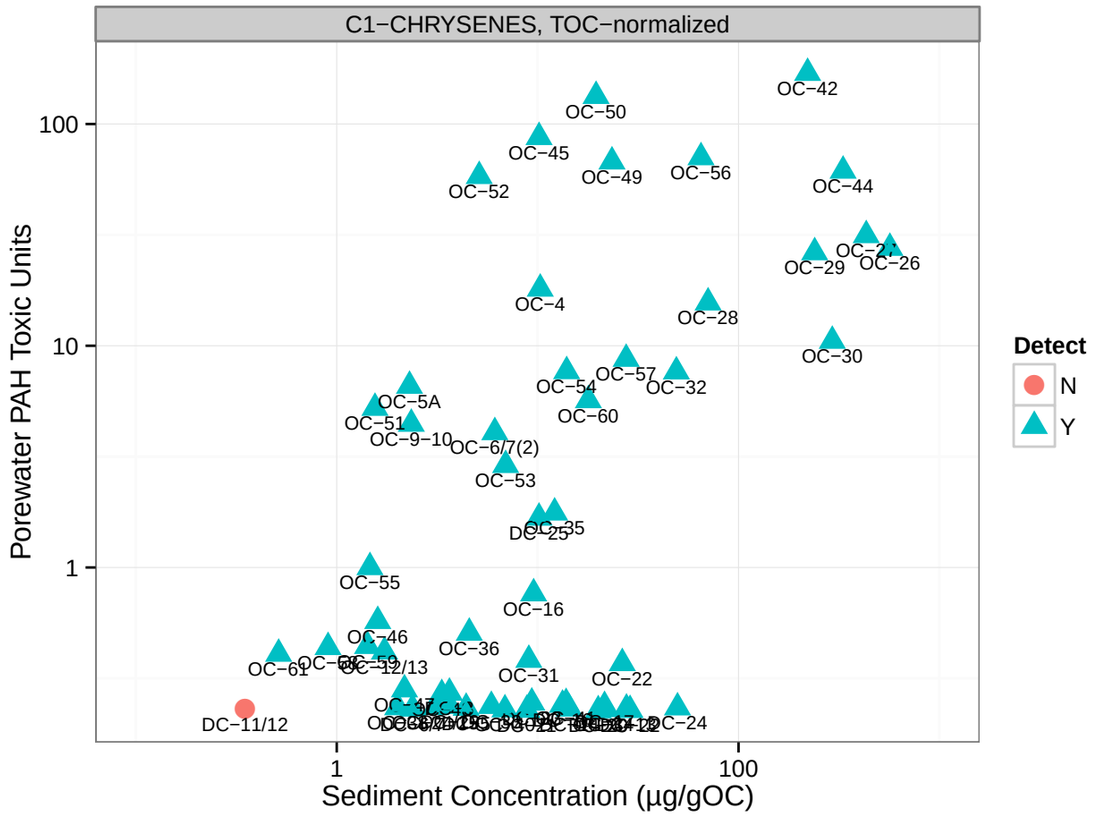

BENZO[A]PYRENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

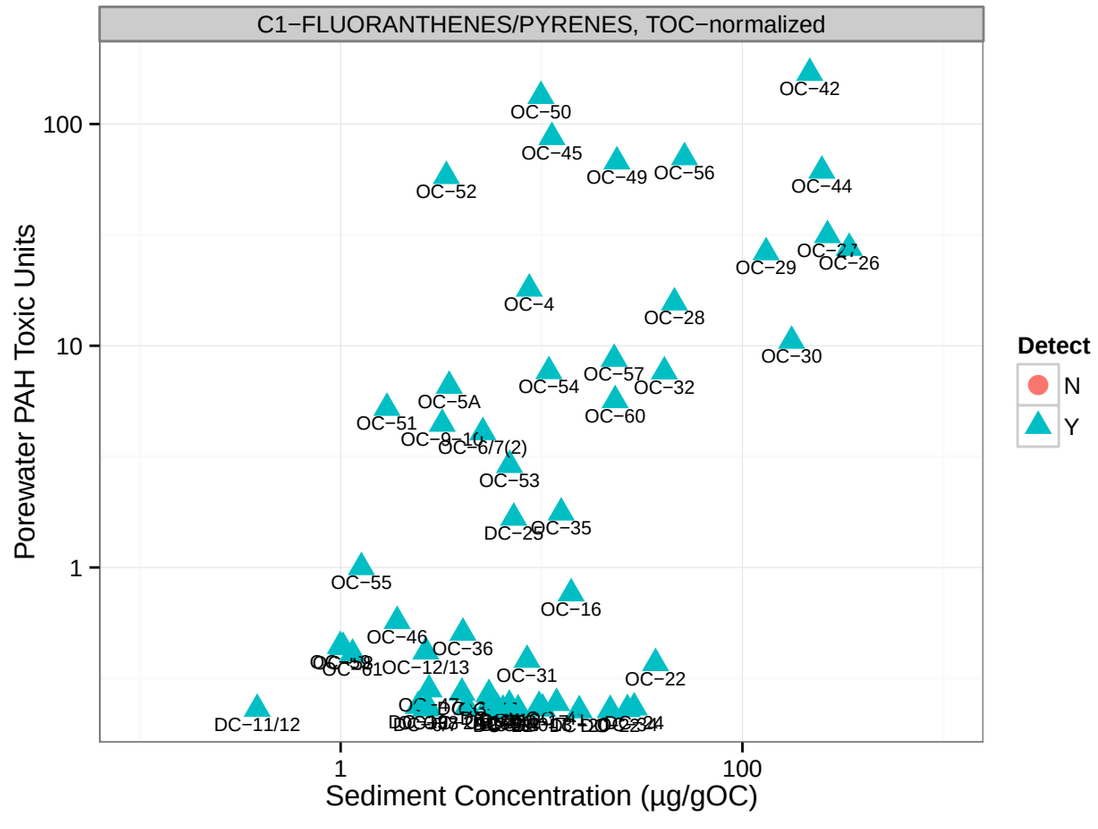

BENZO[B]FLUORANTHENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

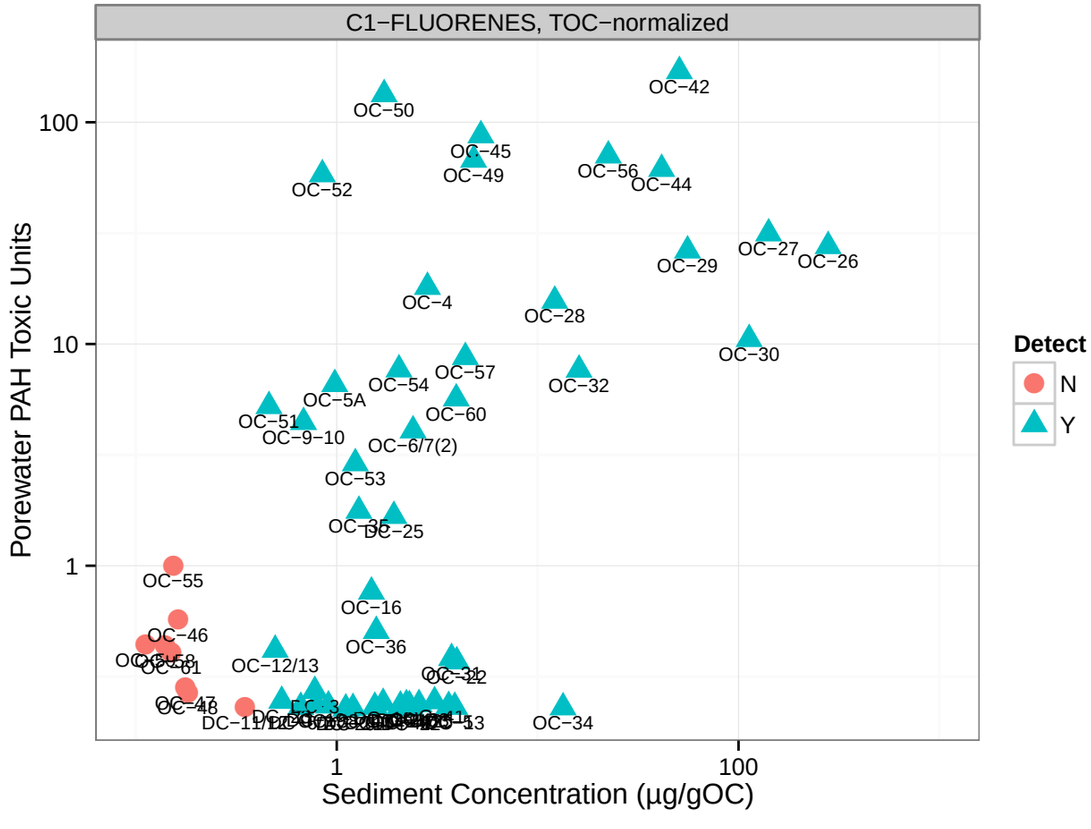

BENZO[E]PYRENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

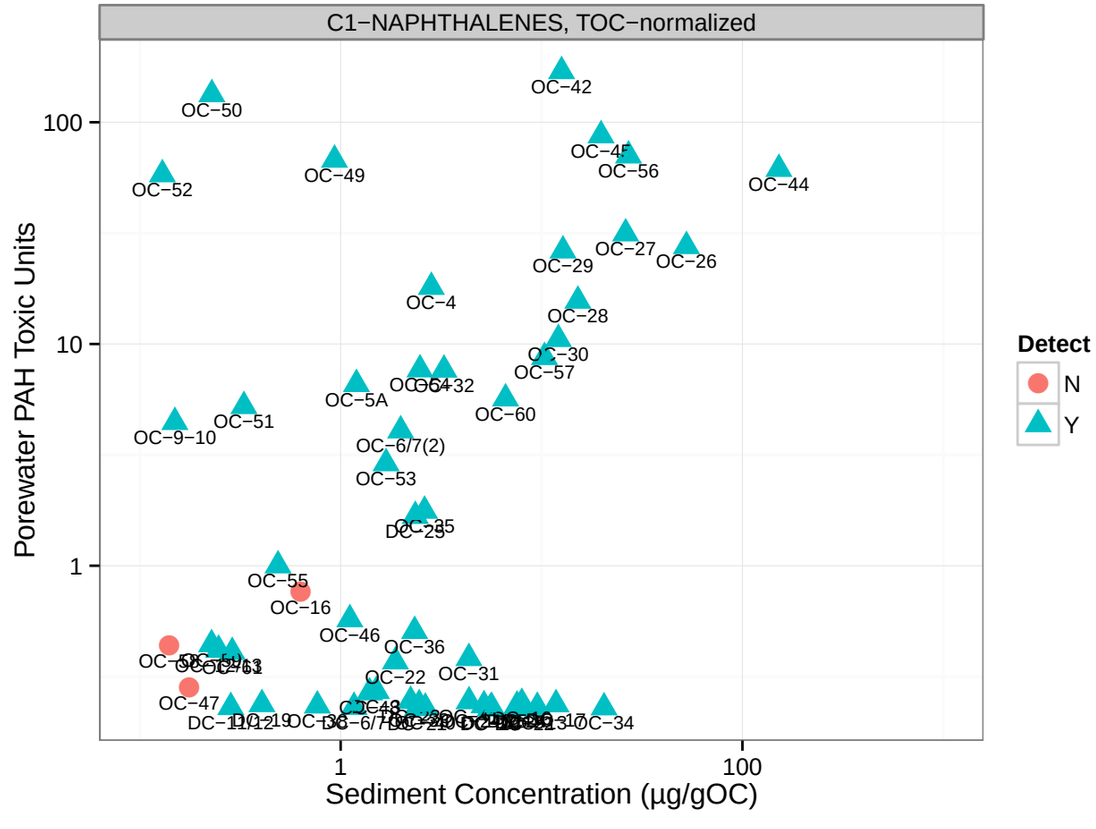

BENZO[G,H,I]PERYLENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

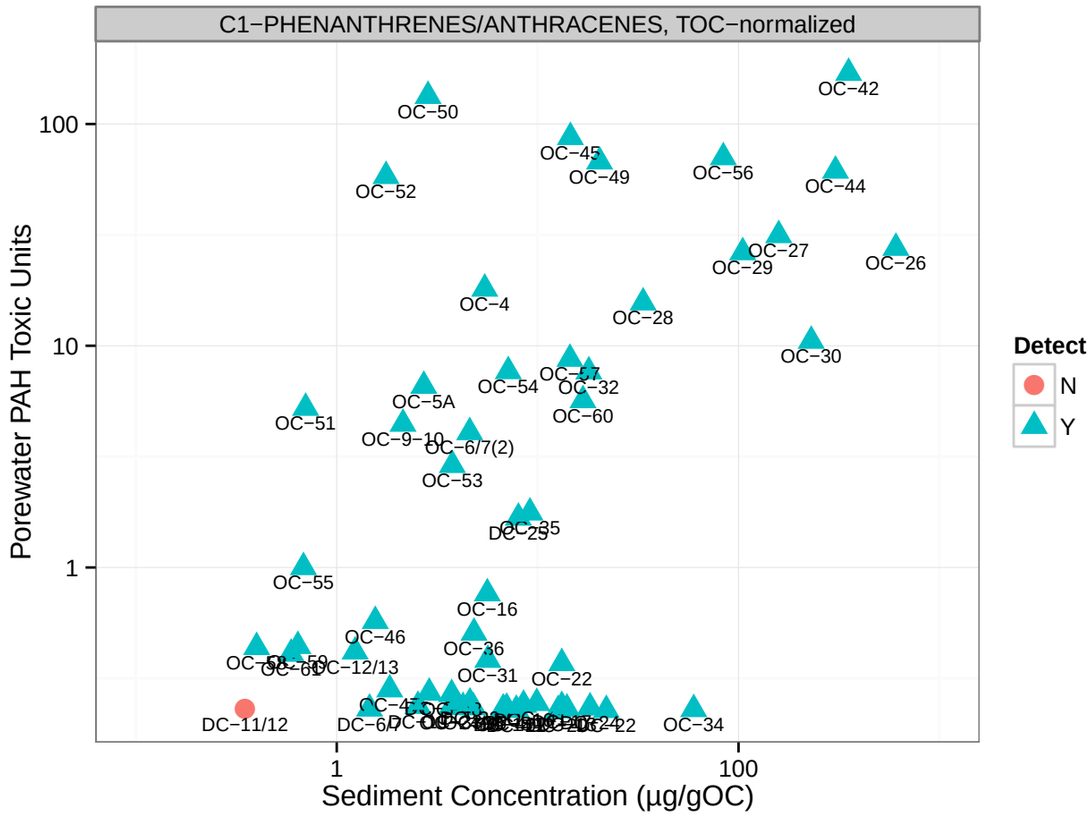

BENZO[K]FLUORANTHENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

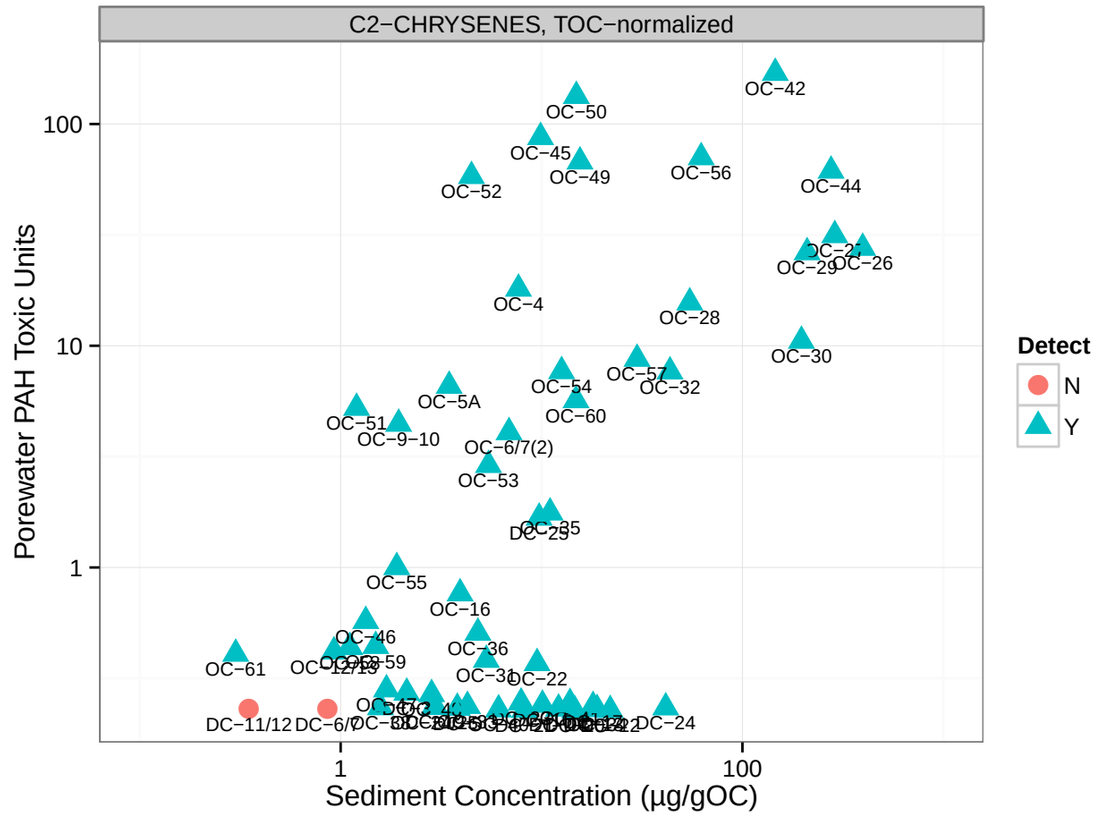

C1−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

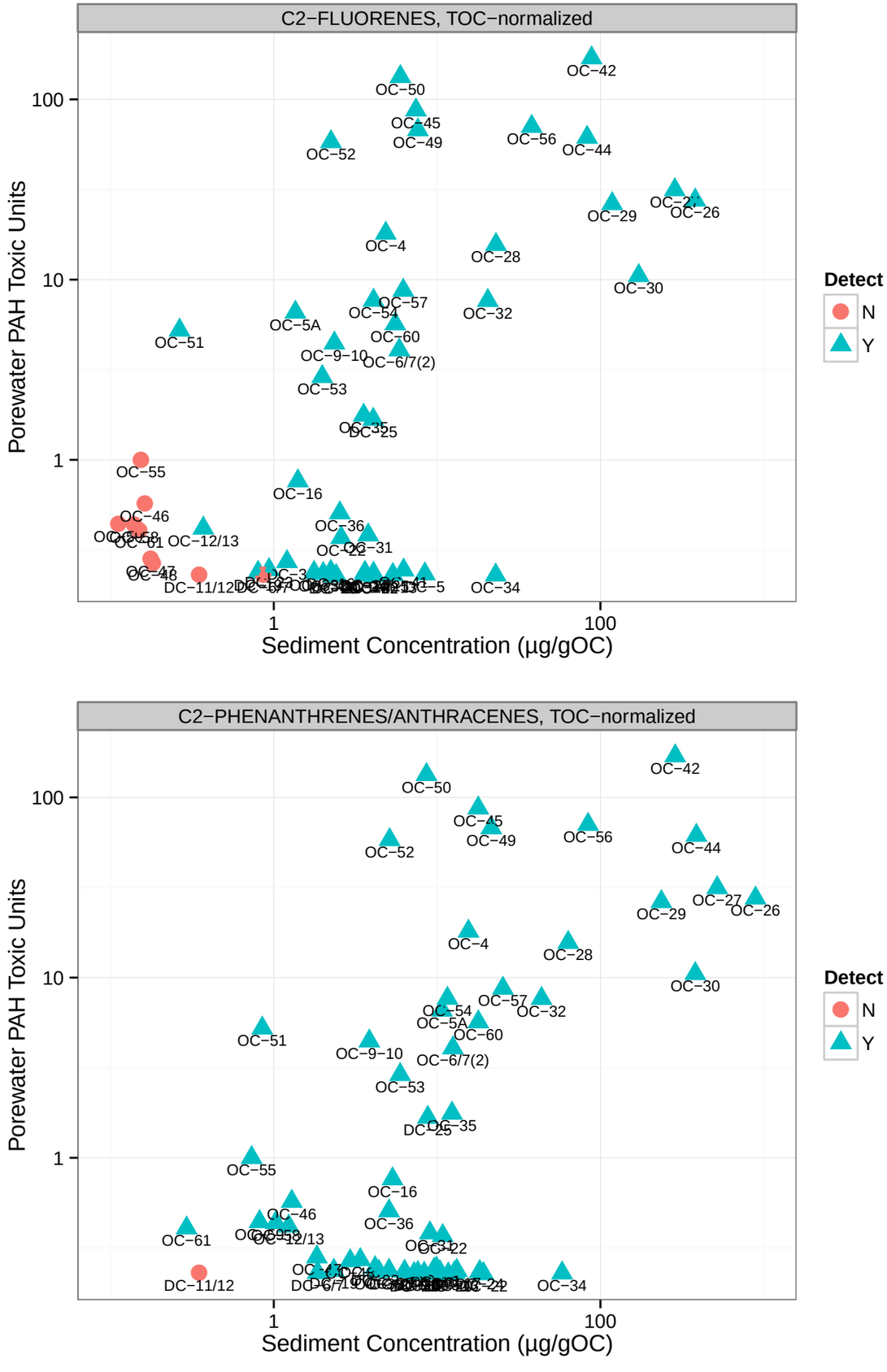

C1−FLUORANTHENES/PYRENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

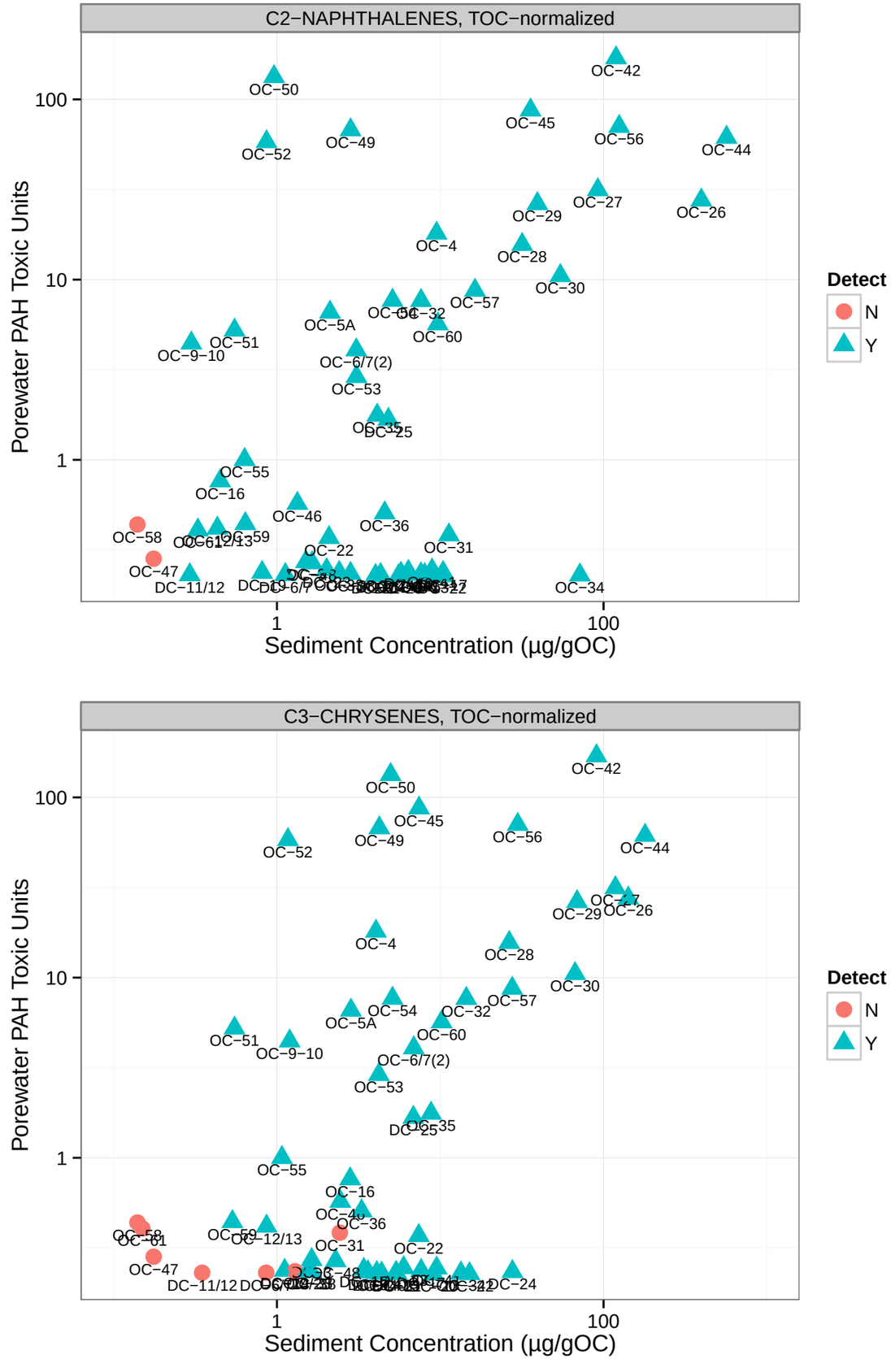

C1−FLUORENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y


C1−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y


C1−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

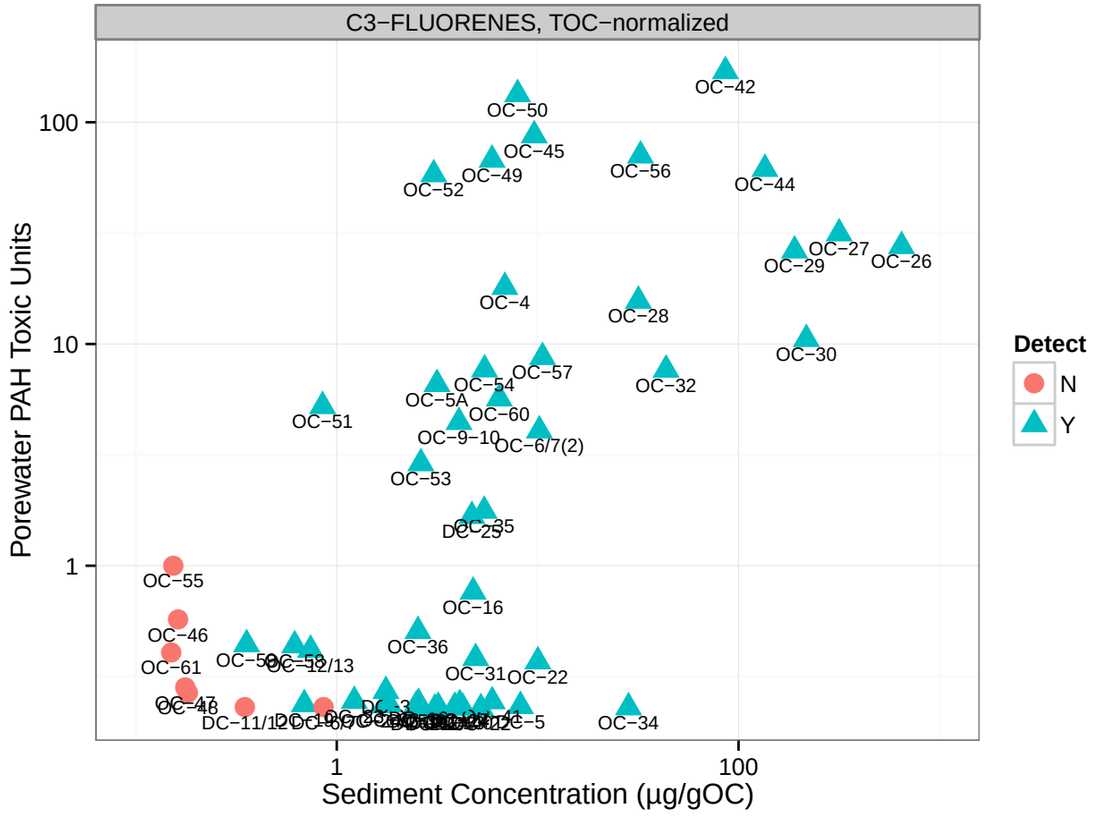

C2−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

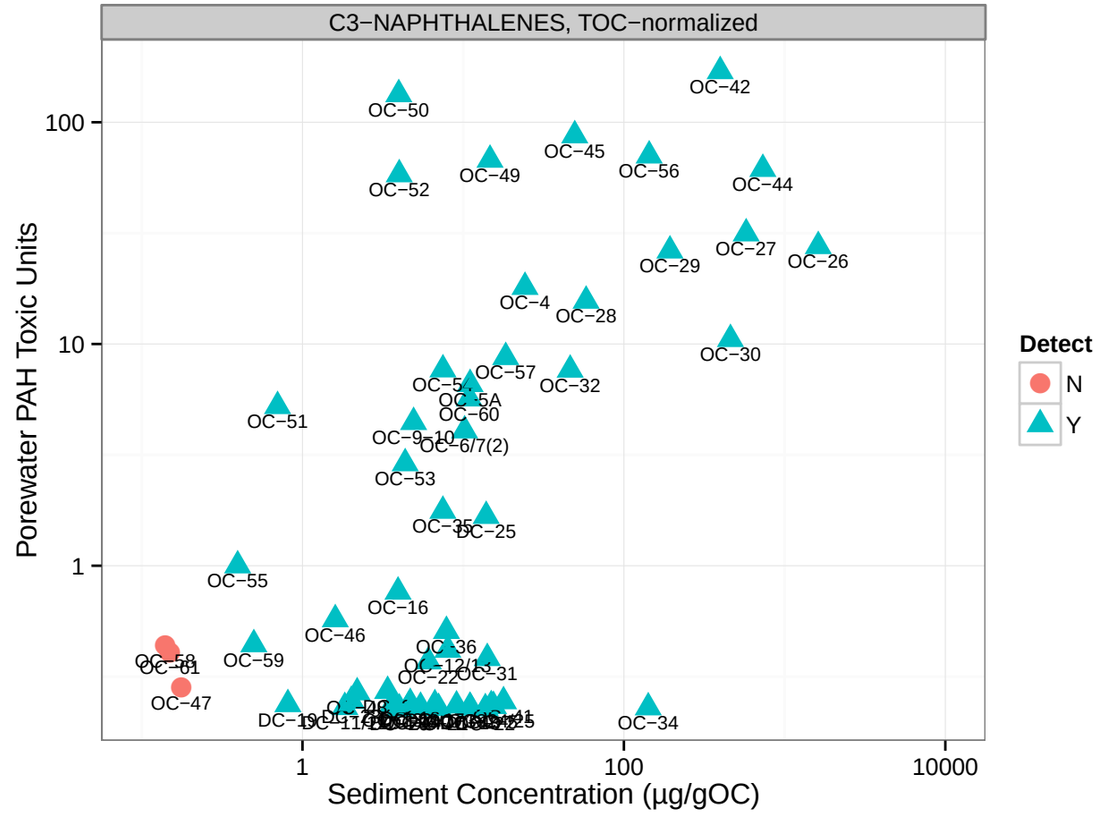

C2−FLUORENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

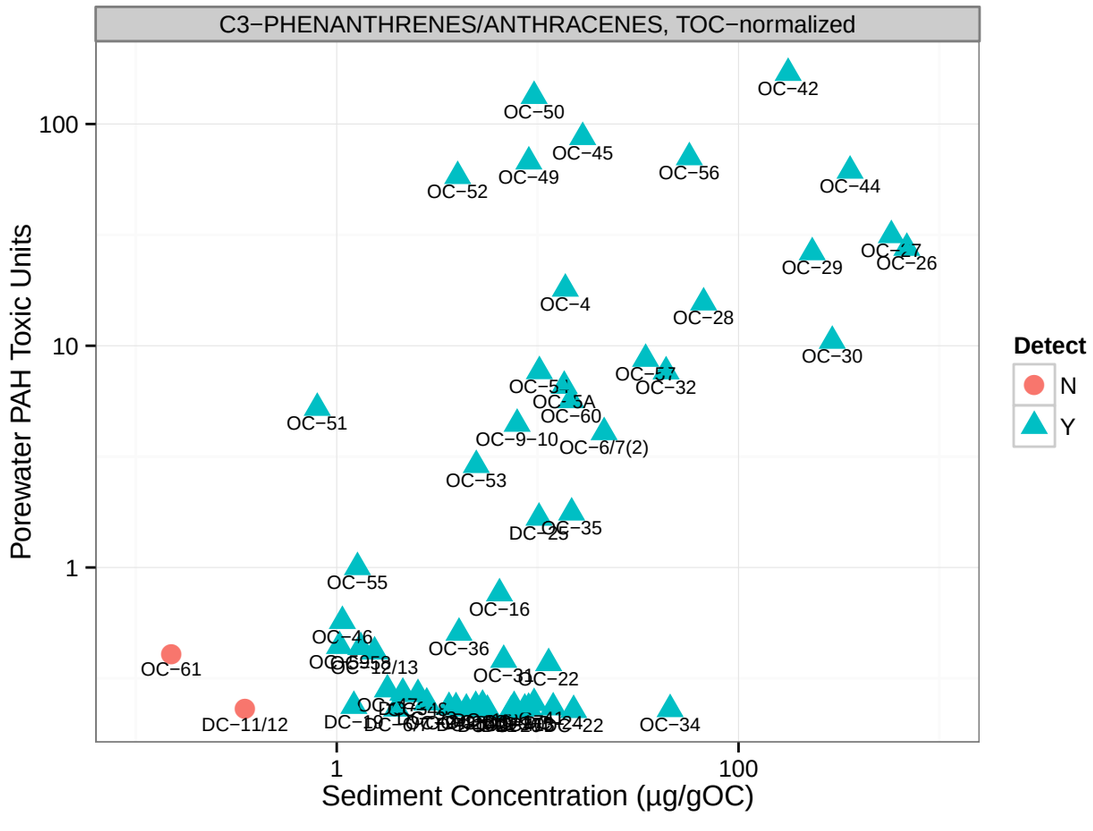

C2−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

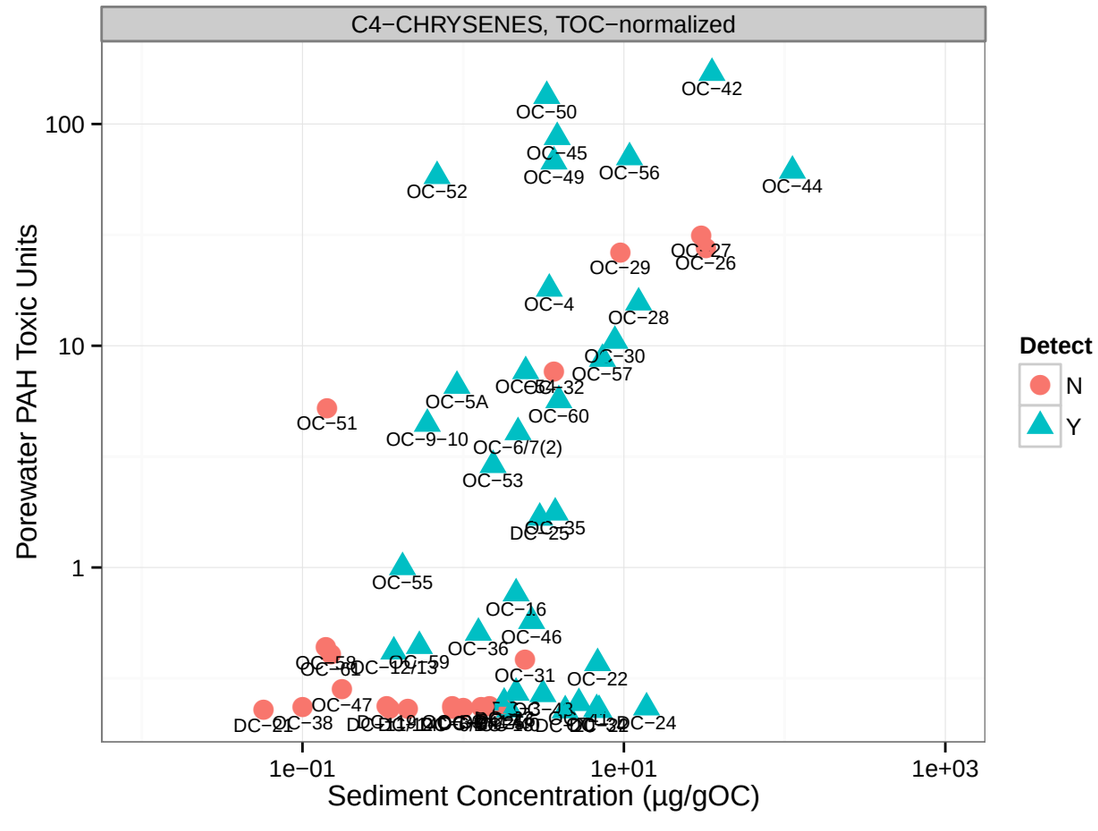
C2−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

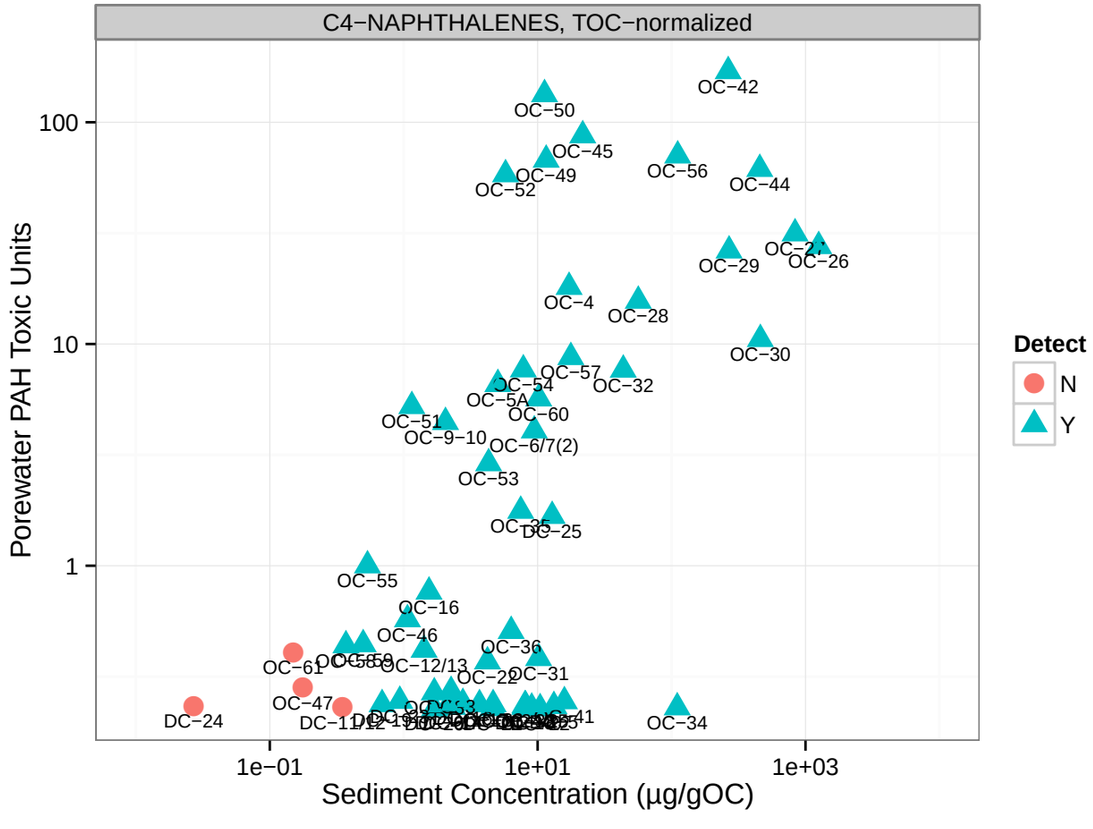
C3−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

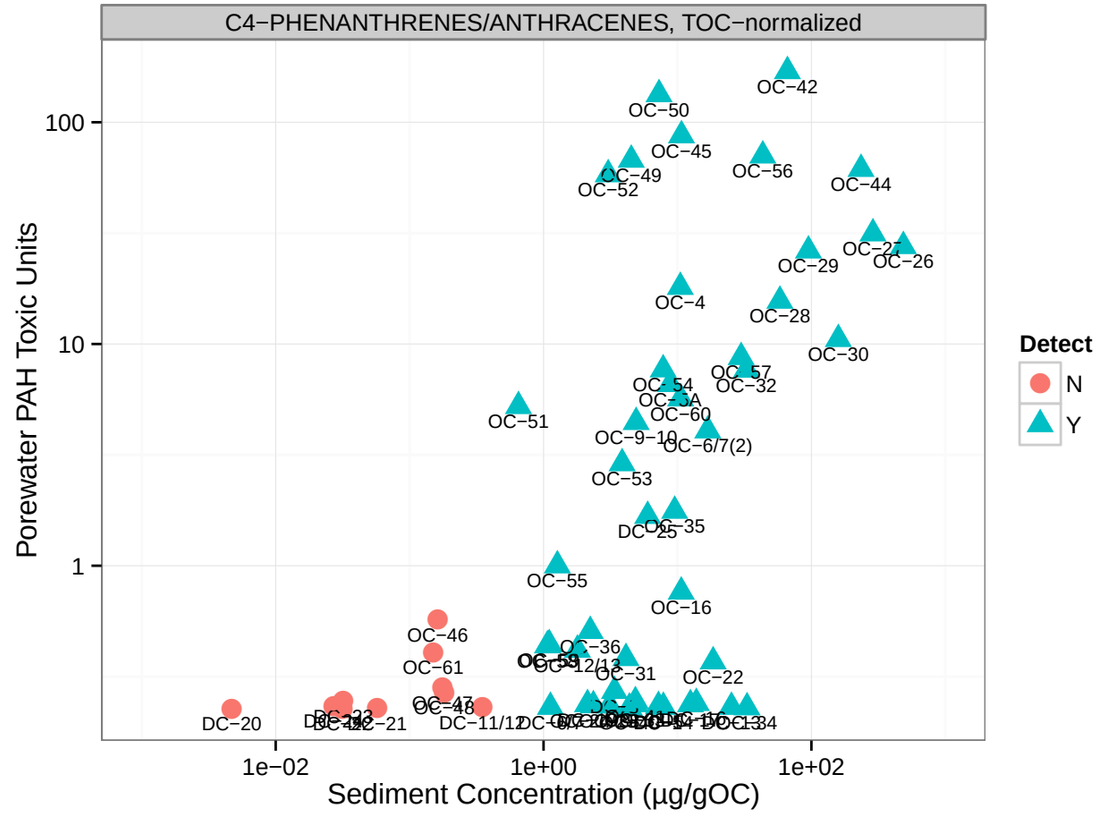

C3−FLUORENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

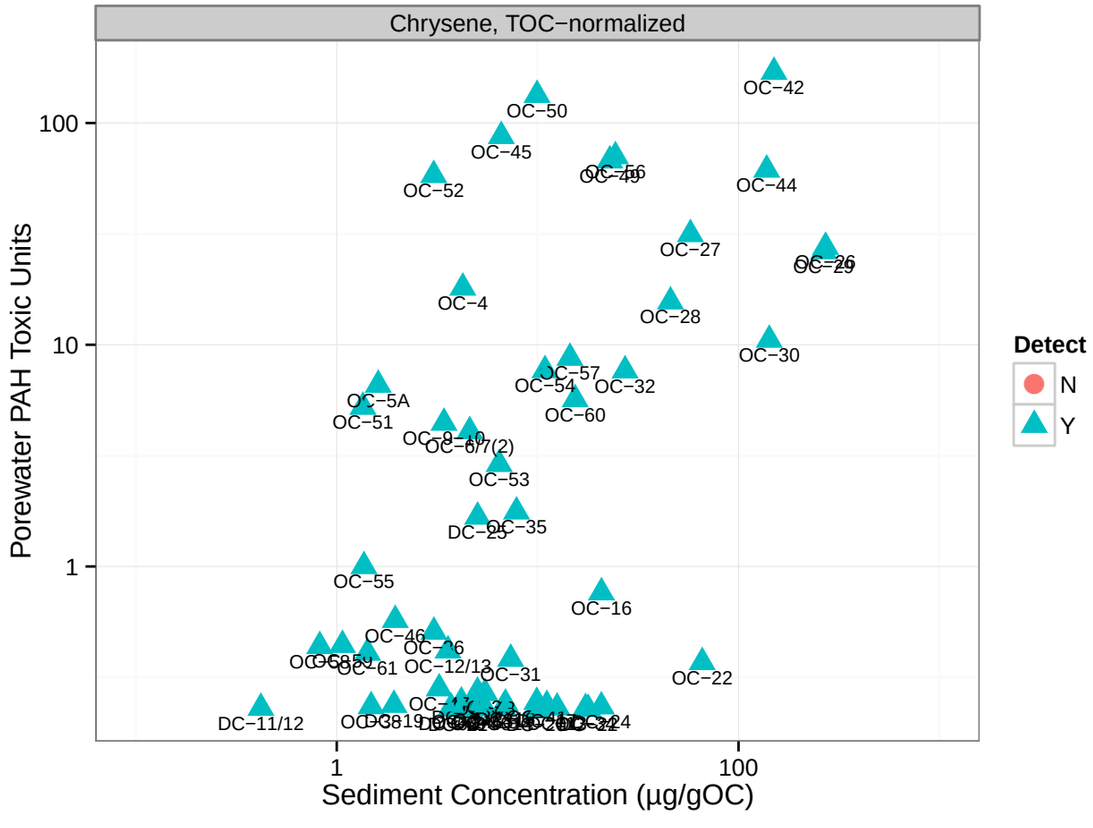

C3−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

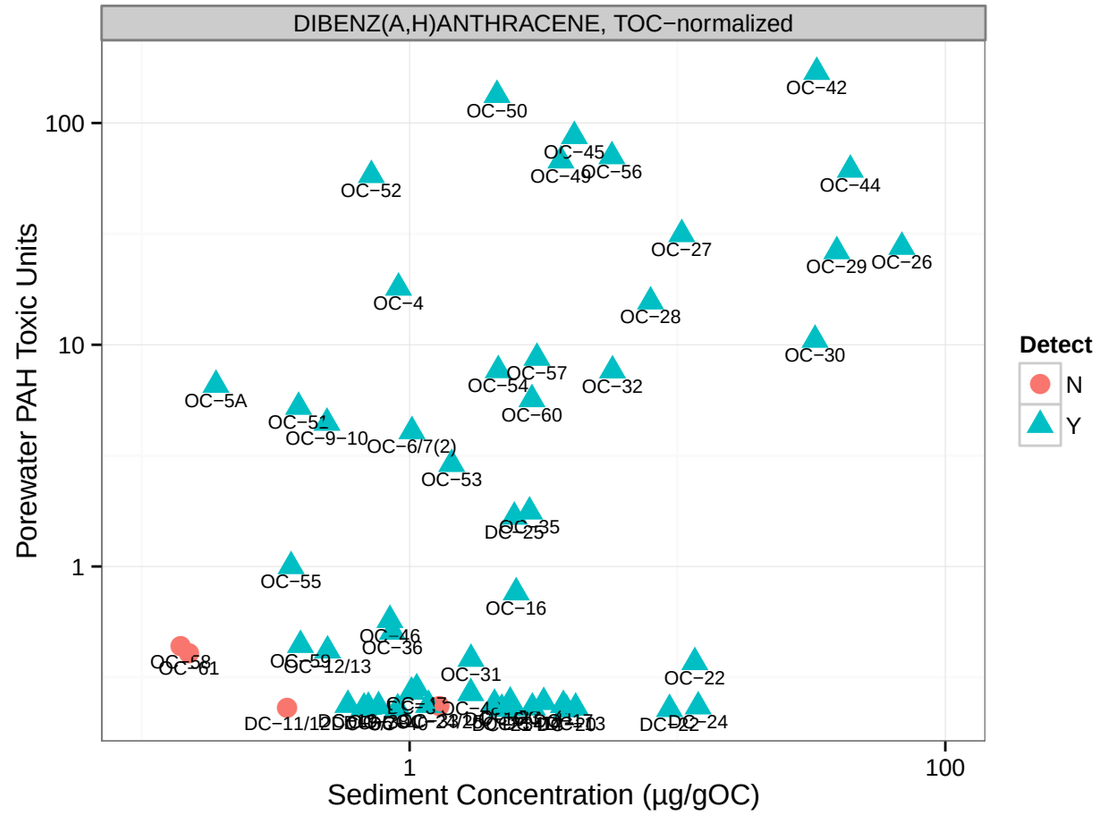

C3−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

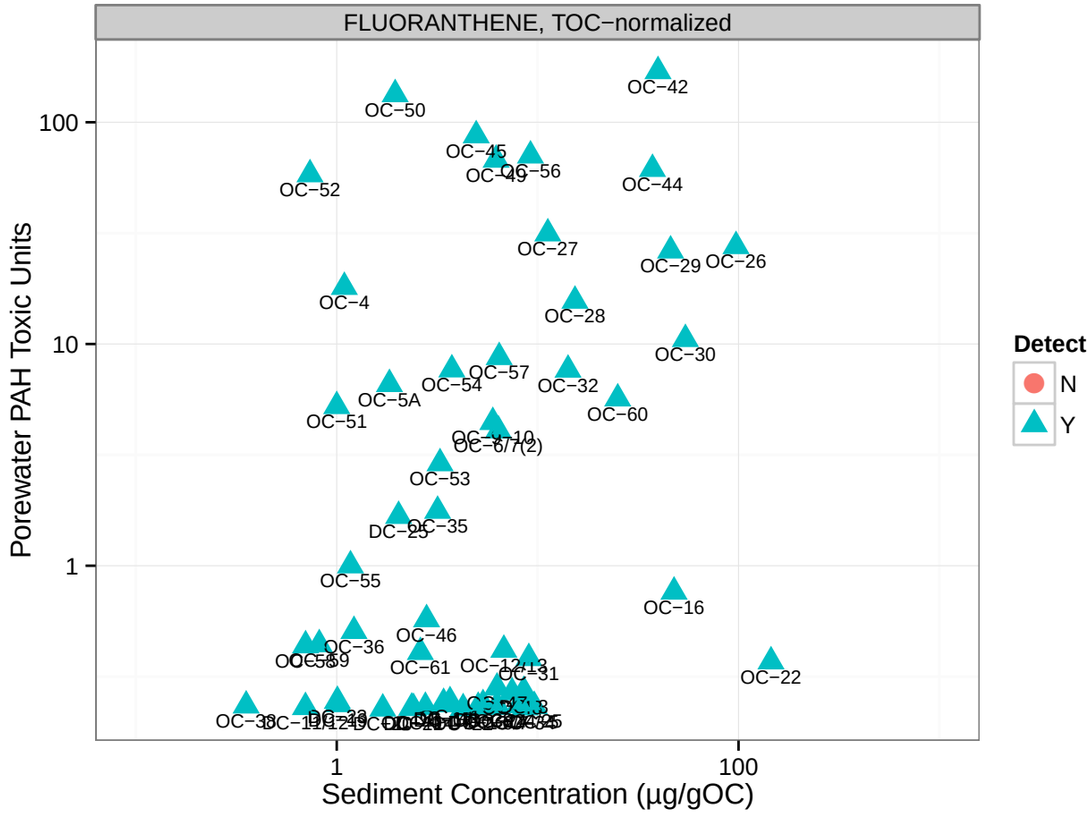

C4−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
Detect
N
Y

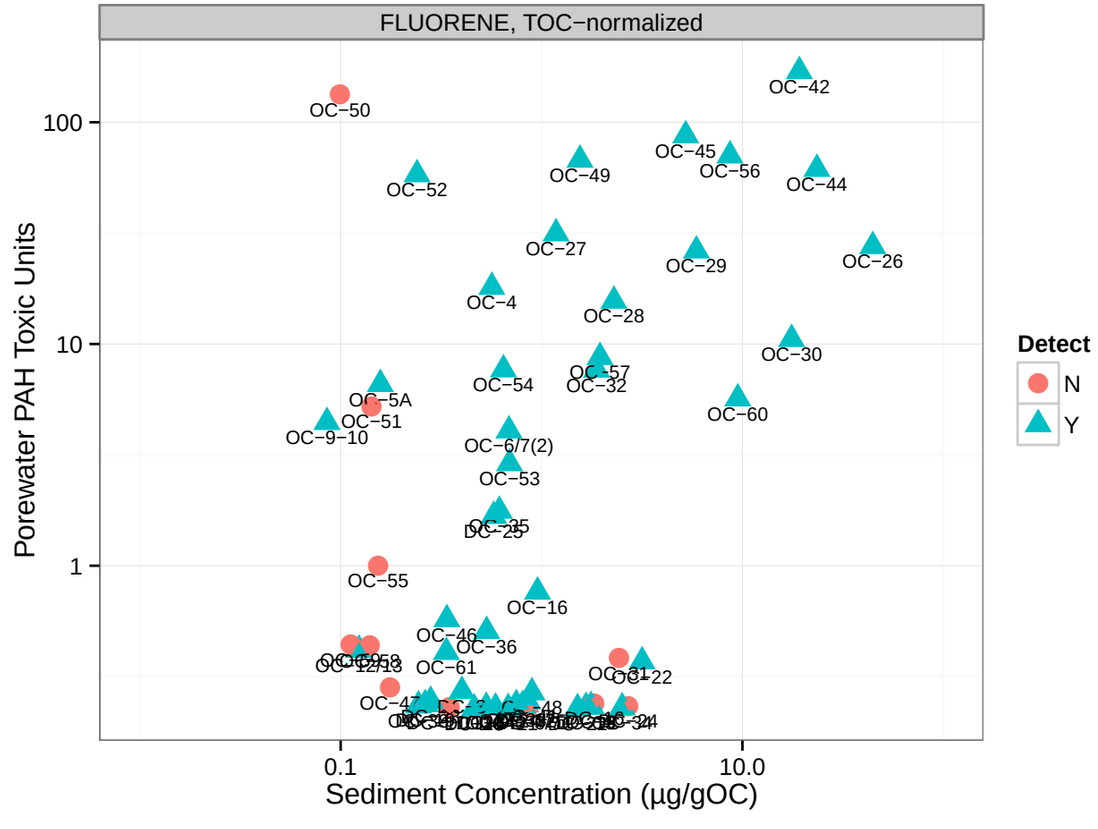

C4−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e−01
1e+01
1e+03
Sediment Concentration (µg/gOC)
Detect
N
Y

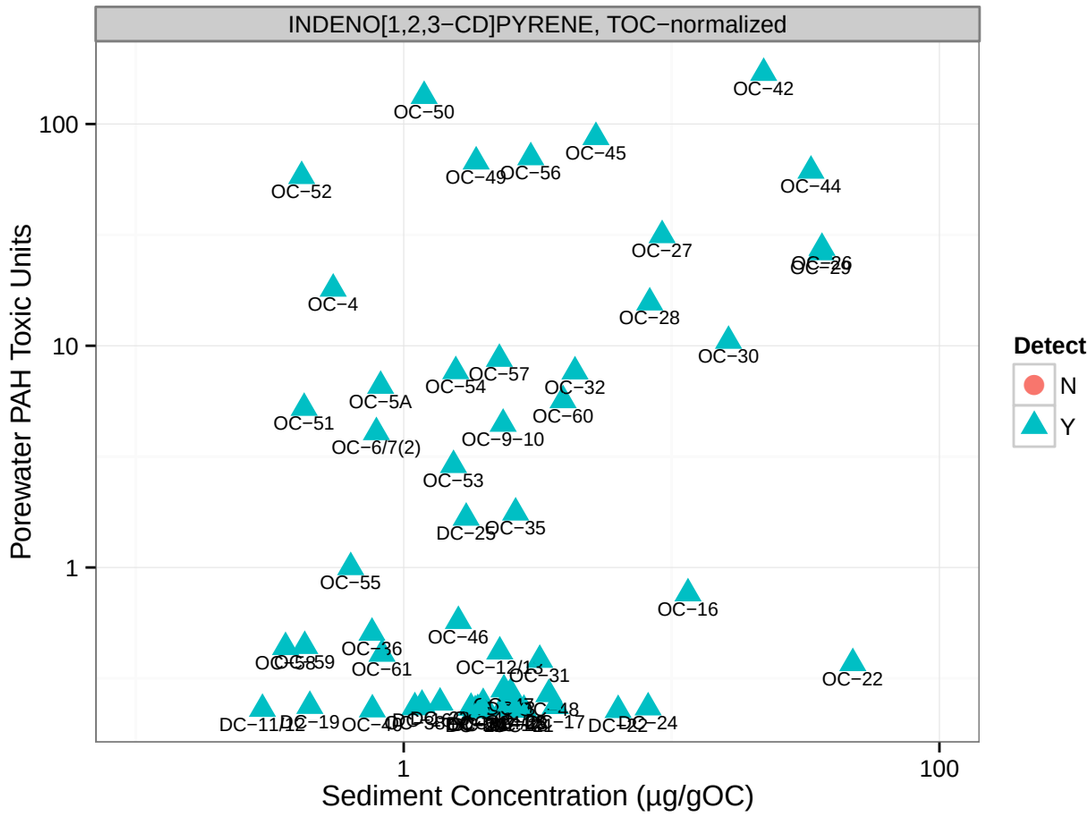

C4−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (µg/gOC)
Detect
N
Y

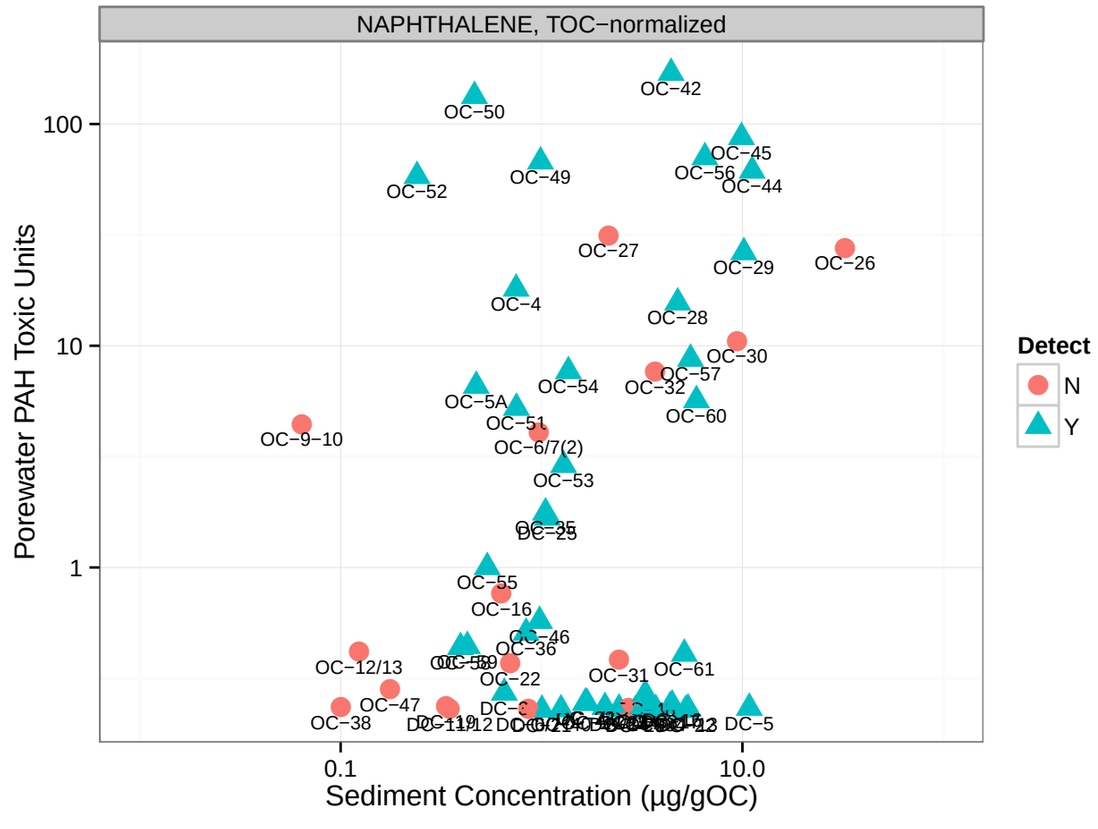

Chrysene, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
Detect
N
Y

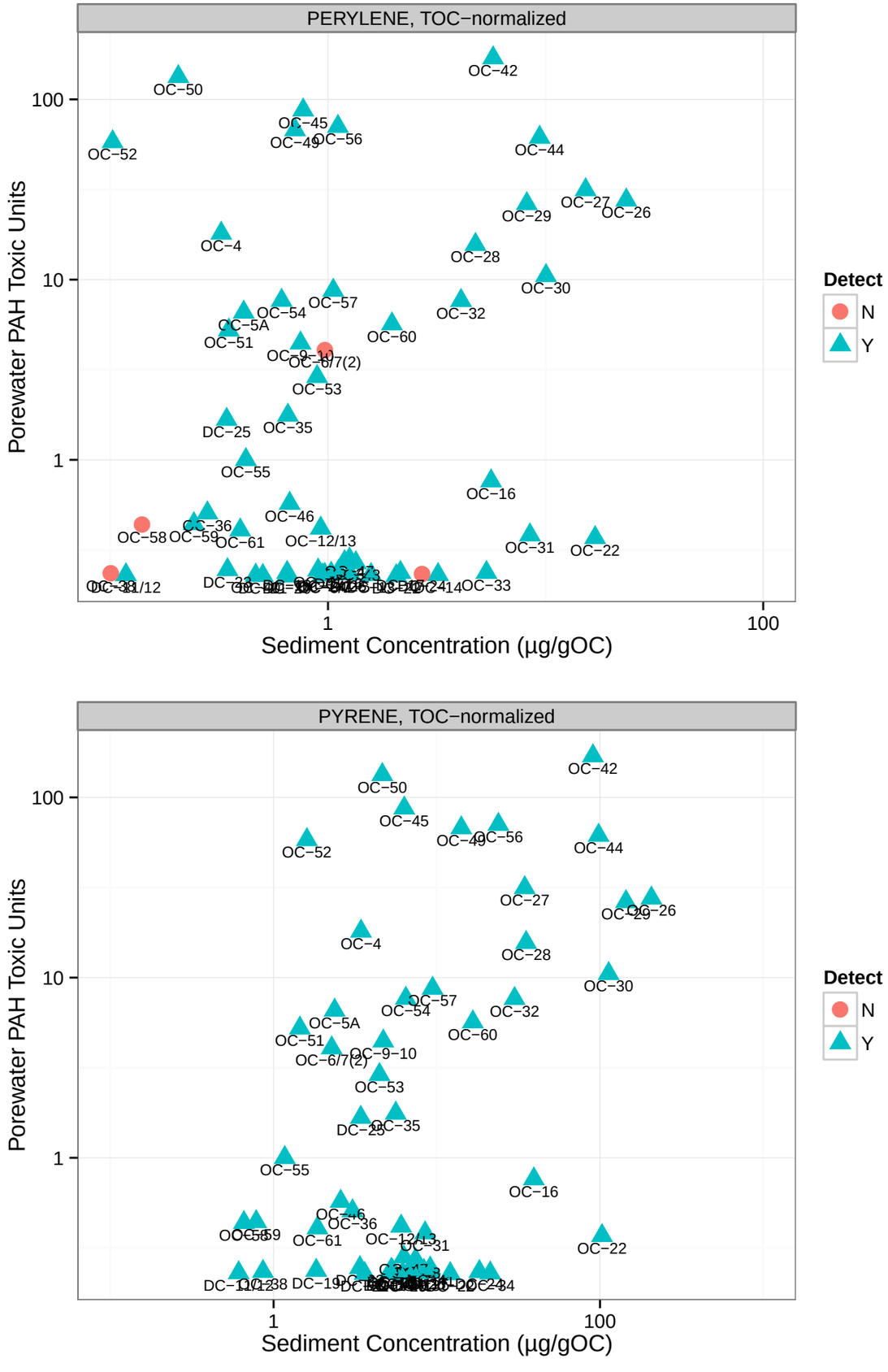

DIBENZ(A,H)ANTHRACENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
Detect
N
Y

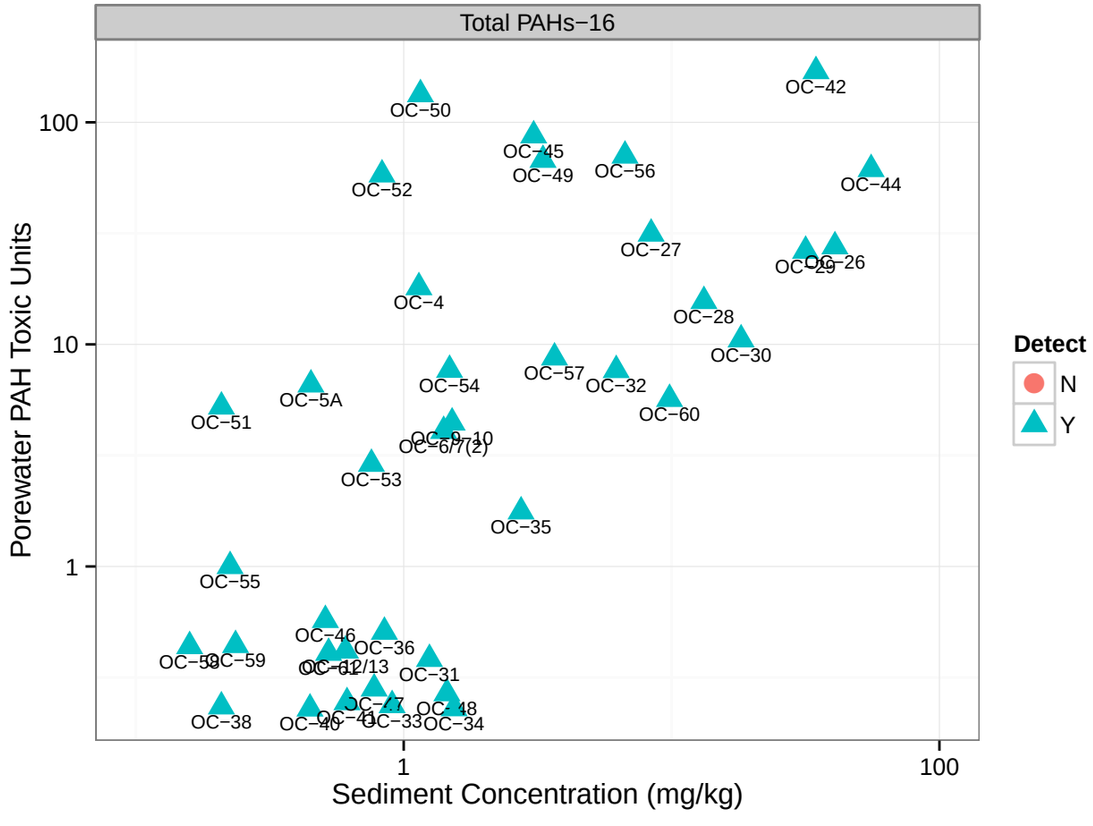

FLUORANTHENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
Detect
N
Y

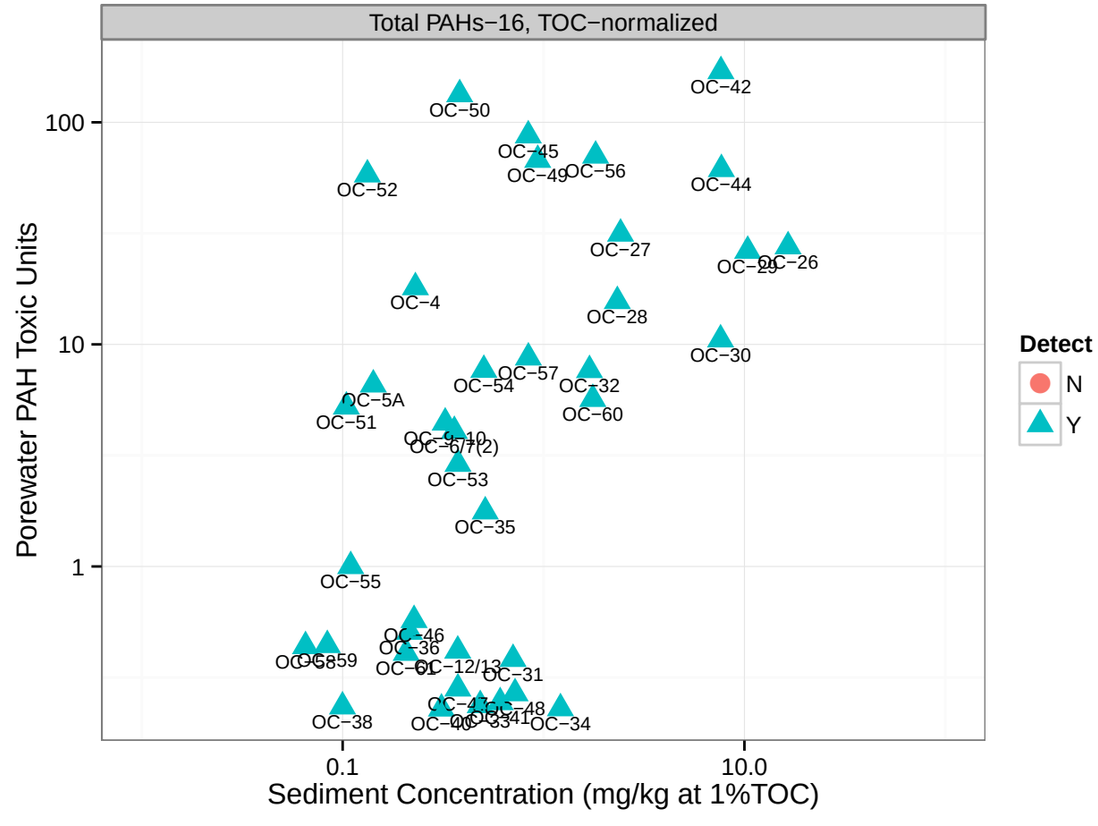

FLUORENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
0.1
10.0
Detect
N
Y

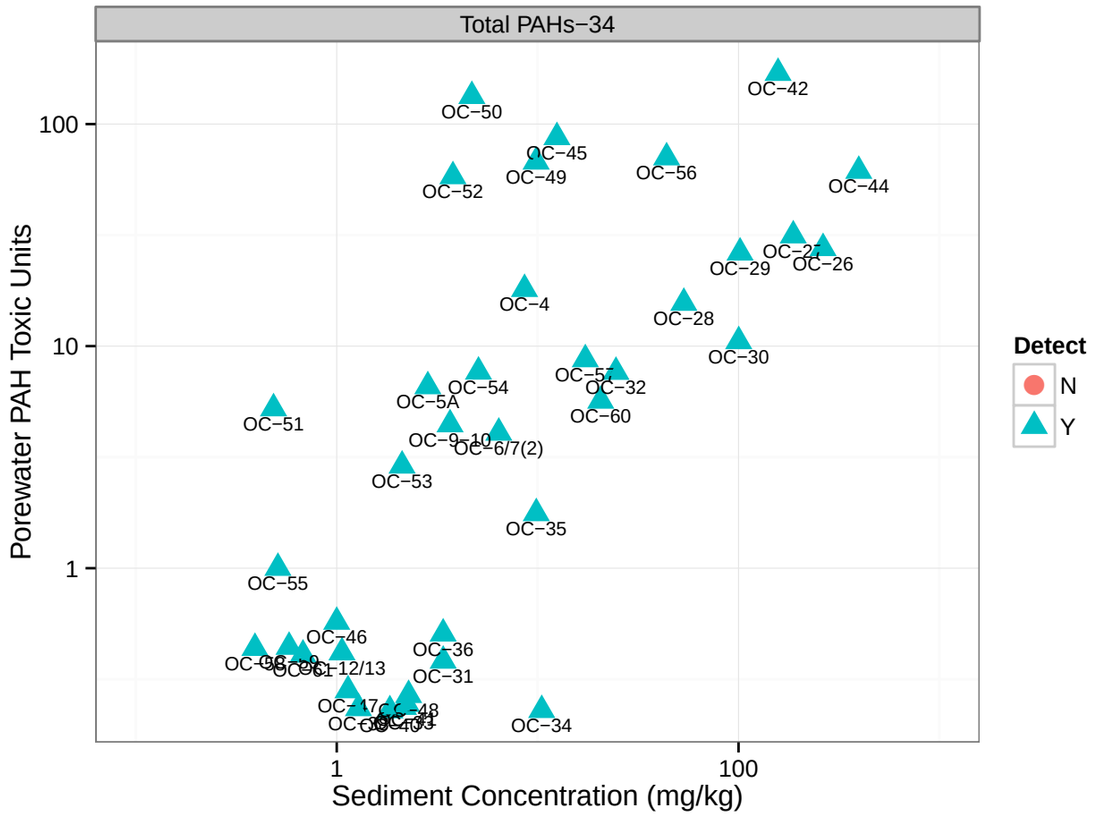

INDENO[1,2,3−CD]PYRENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
Detect
N
Y

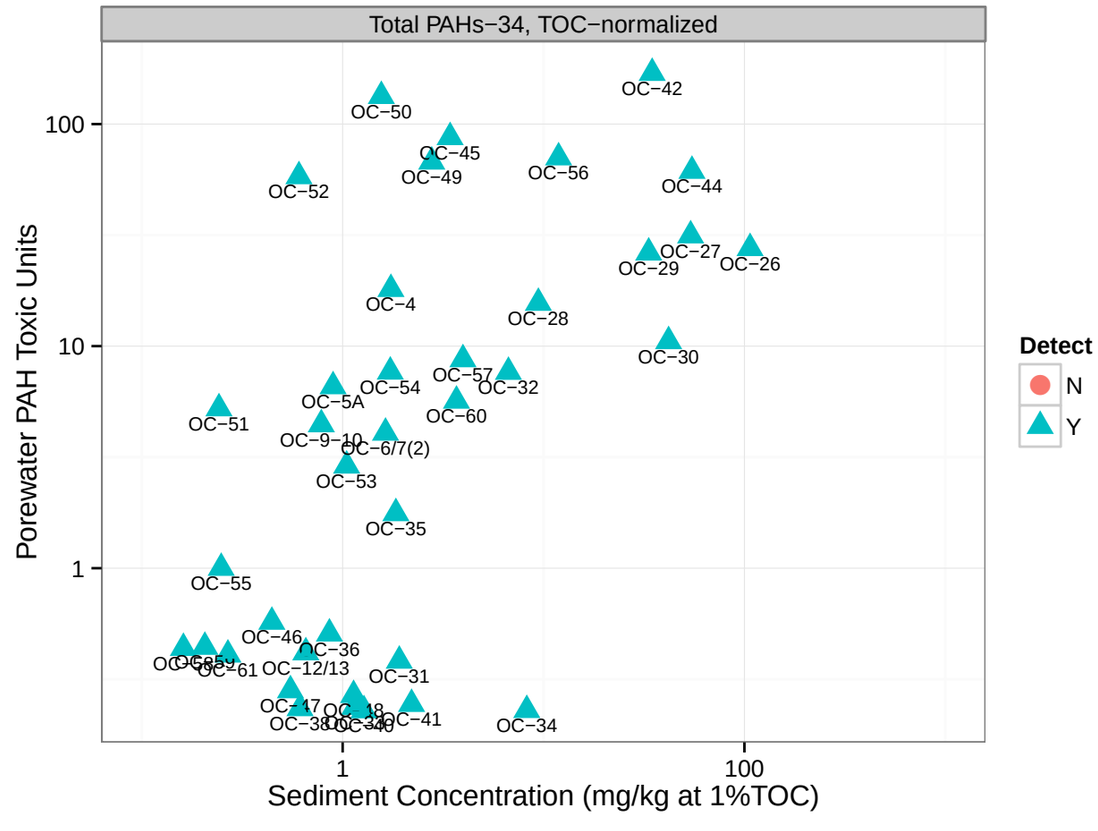

NAPHTHALENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
0.1
10.0
Detect
N
Y

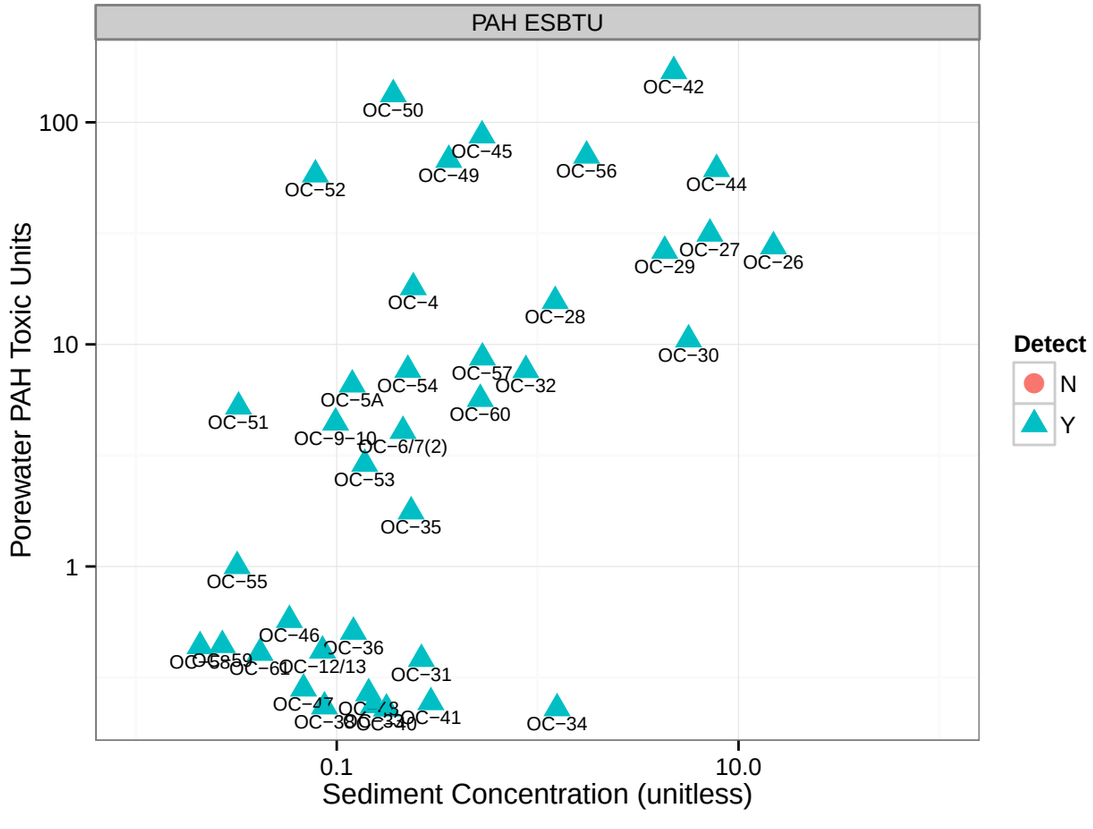

PERYLENE, TOC−normalized
PHENANTHRENE, TOC−normalized
PYRENE, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
Detect
N
Y

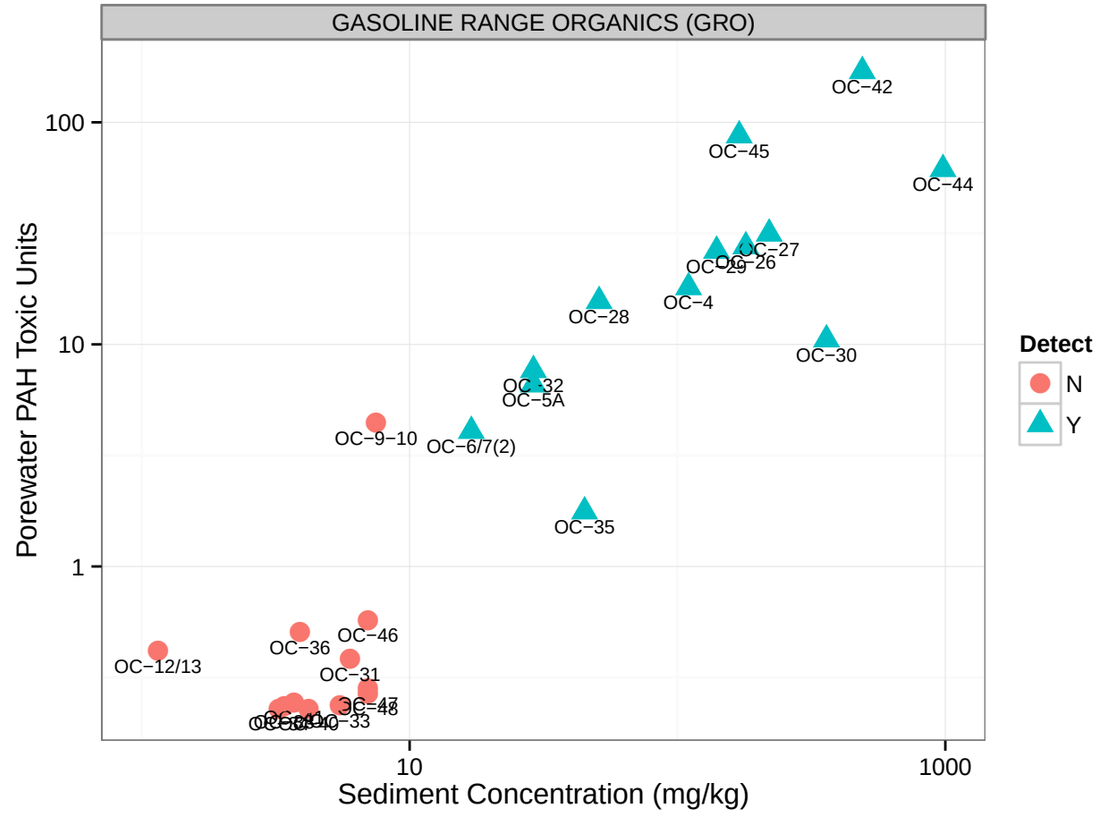

Total PAHs−16
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−41
OC−33
OC−34
Detect
N
Y

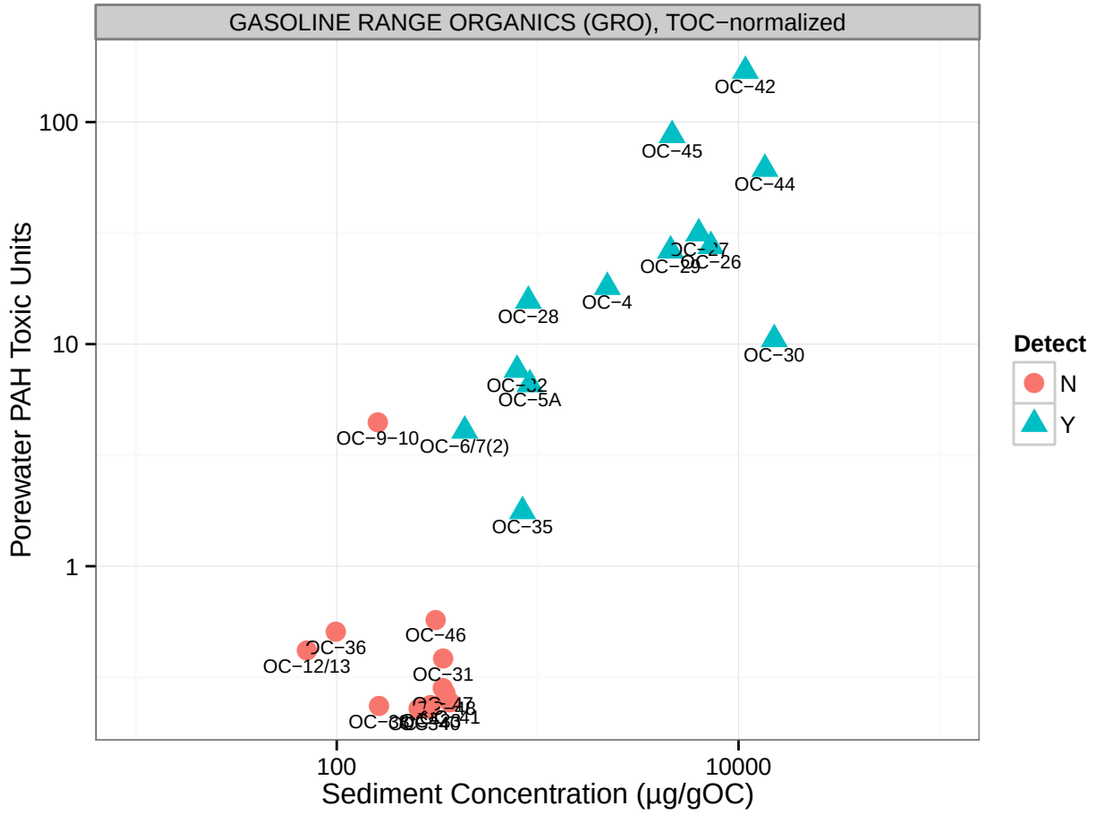

Total PAHs−16, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg at 1%TOC)
0.1
10.0
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−41
OC−33
OC−34
Detect
N
Y

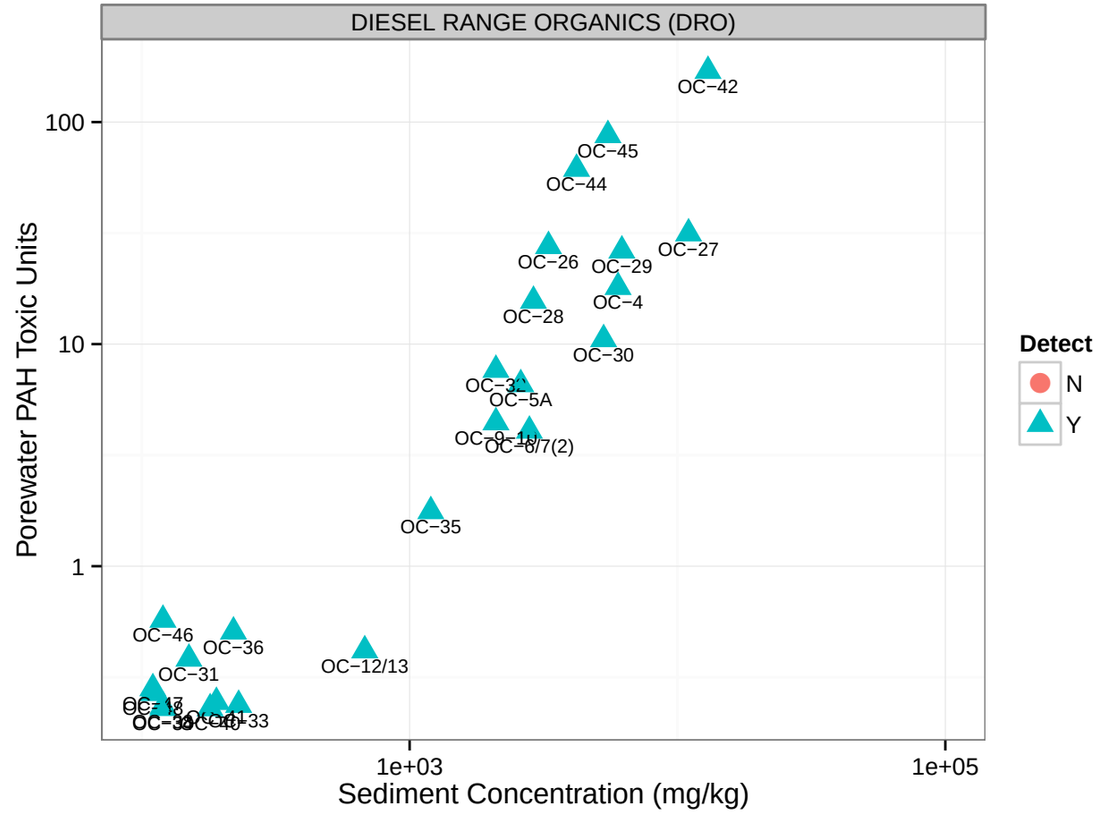

Total PAHs−34
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−34
Detect
N
Y

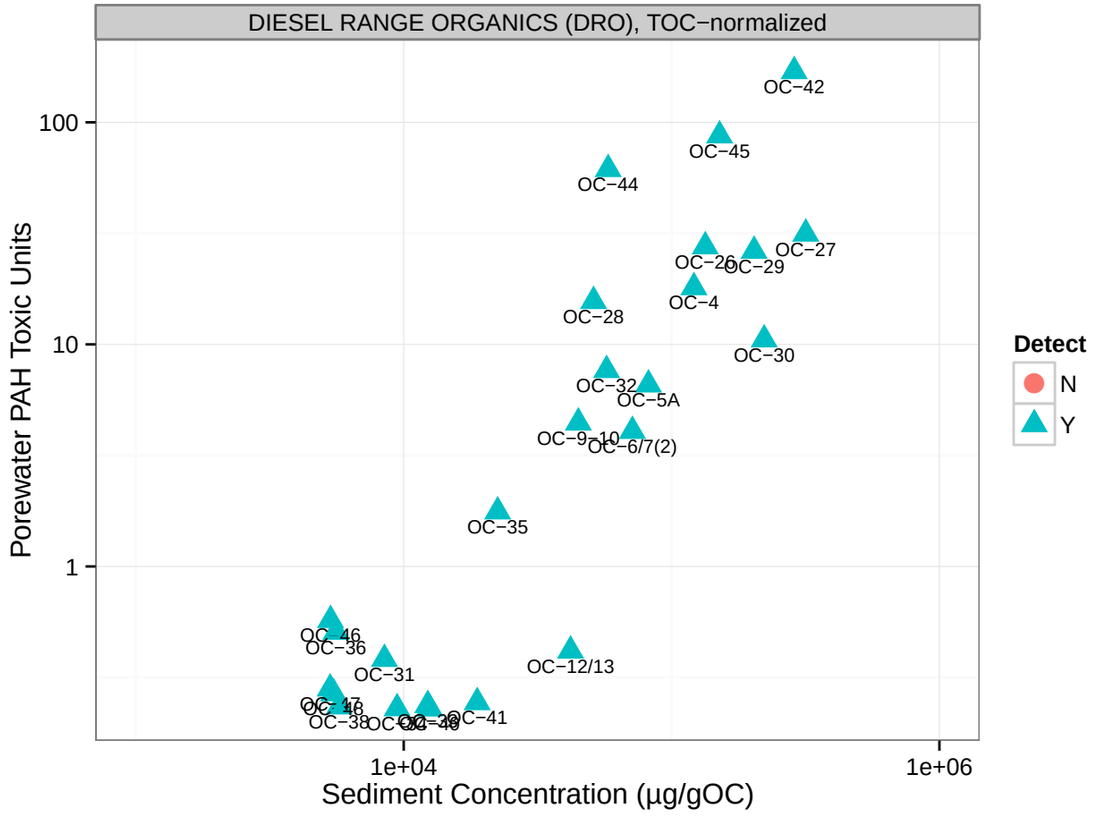

Total PAHs−34, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (mg/kg at 1%TOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−12/13
OC−31
OC−47
OC−34
OC−41
Detect
N
Y

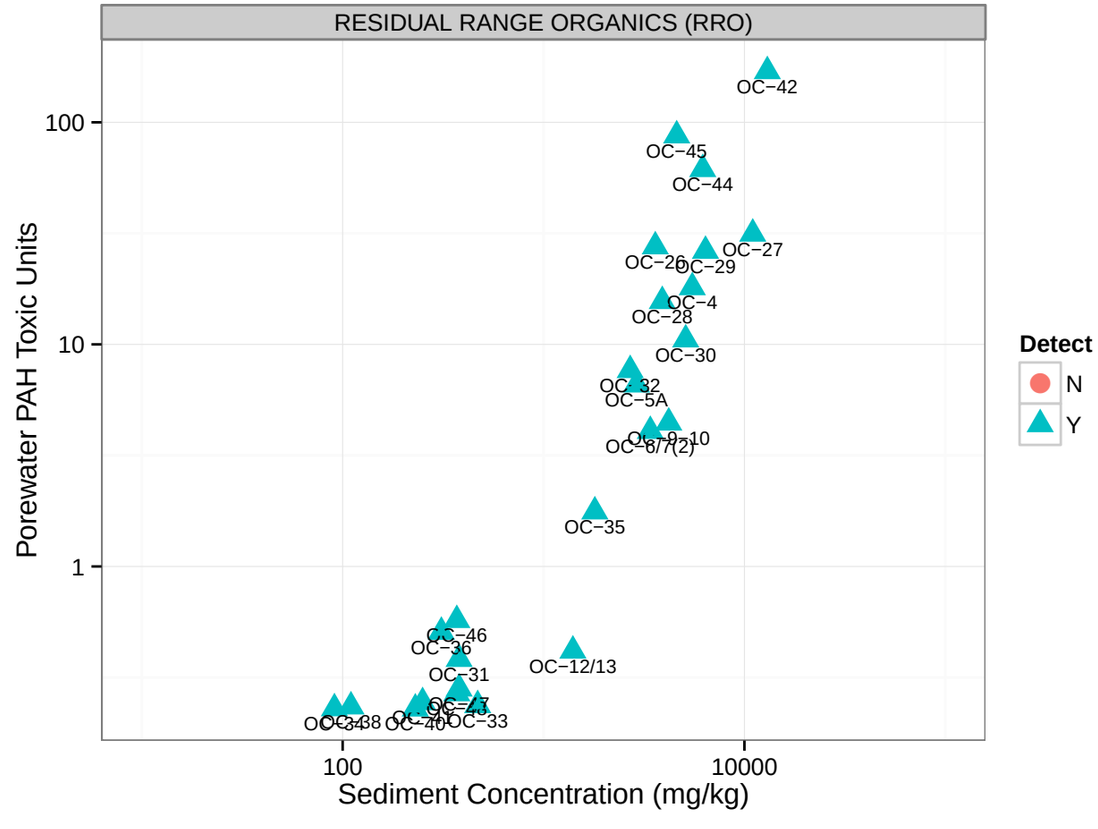

PAH ESBTU
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (unitless)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−41
OC−34
Detect
N
Y

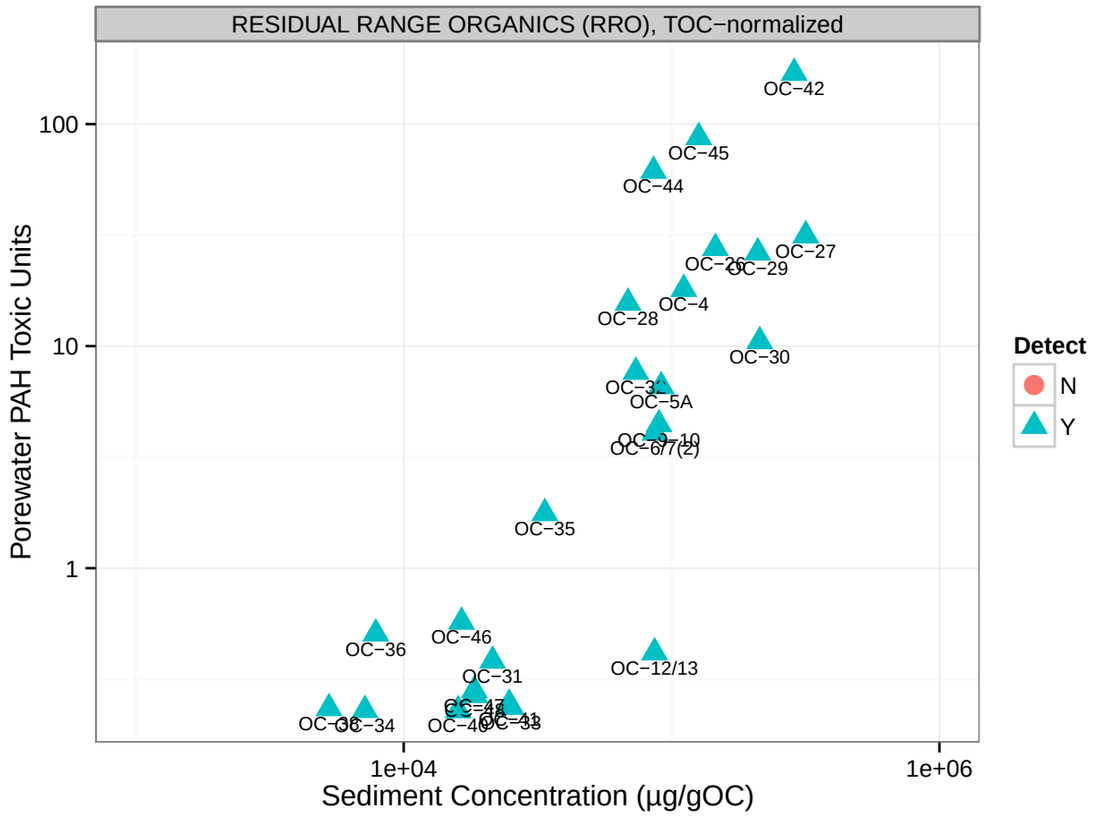

GASOLINE RANGE ORGANICS (GRO)
Porewater PAH Toxic Units
100
10
1
10
1000
Sediment Concentration (mg/kg)
OC−42
OC−45
OC−44
OC−27
OC−26
OC−29
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9−10
OC−6/7(2)
OC−35
OC−12/13
OC−46
OC−36
OC−31
OC−33
Detect
N
Y

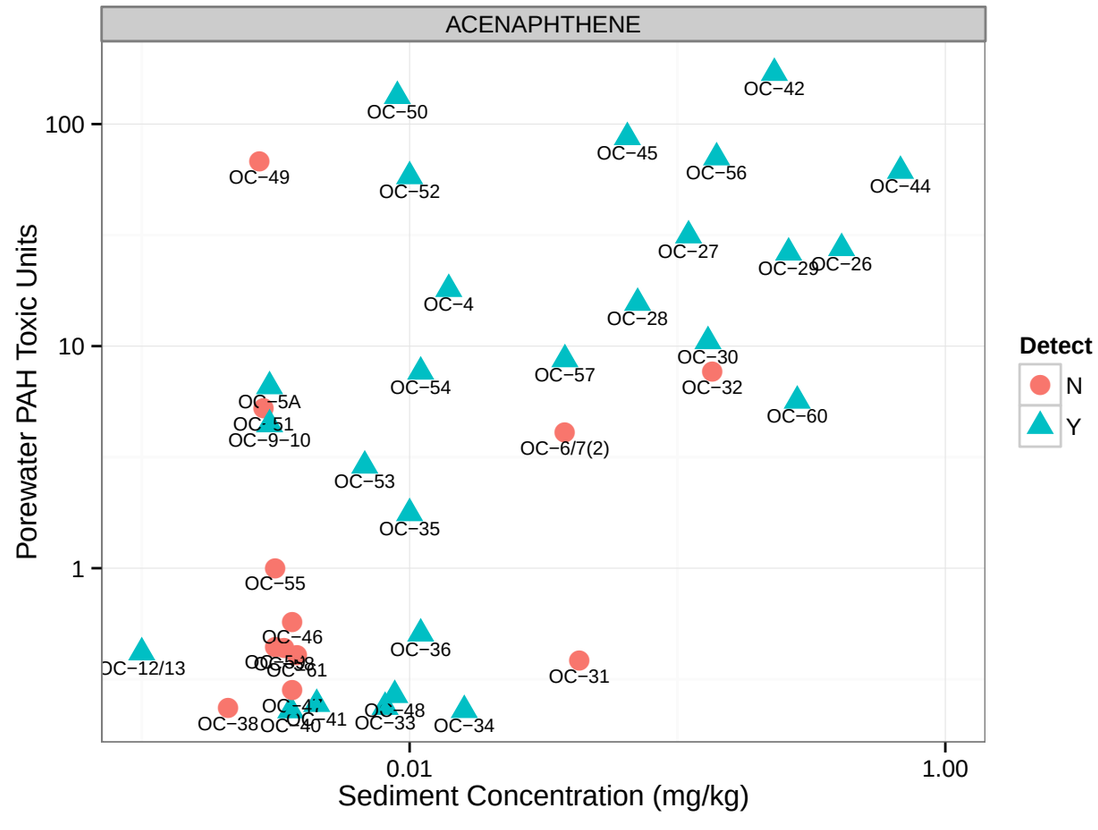

GASOLINE RANGE ORGANICS (GRO), TOC−normalized
Porewater PAH Toxic Units
100
10
1
100
10000
Sediment Concentration (µg/gOC)
OC−42
OC−45
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9−10
OC−6/7(2)
OC−35
OC−46
OC−36
OC−12/13
OC−31
Detect
N
Y

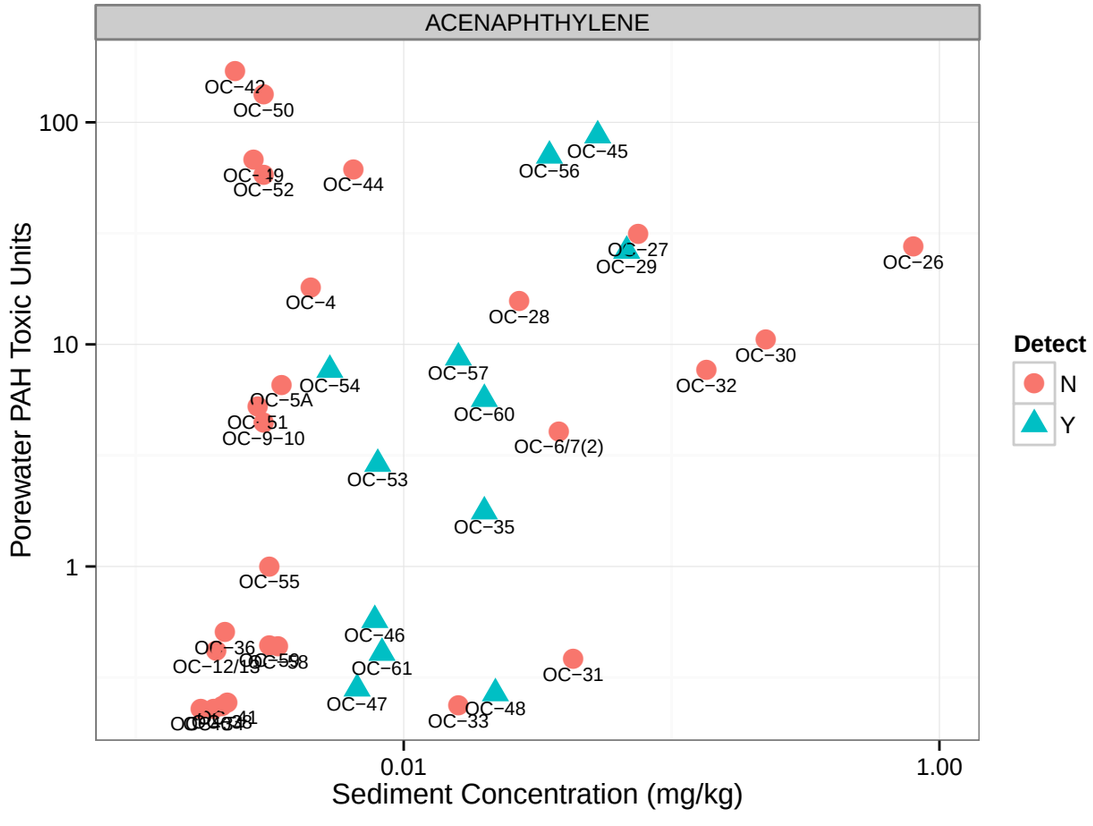

DIESEL RANGE ORGANICS (DRO)
Porewater PAH Toxic Units
100
10
1
1e+03
1e+05
Sediment Concentration (mg/kg)
OC−42
OC−45
OC−44
OC−26
OC−29
OC−27
OC−4
OC−28
OC−30
OC−5A
OC−6/7(2)
OC−35
OC−46
OC−36
OC−12/13
OC−31
Detect
N
Y

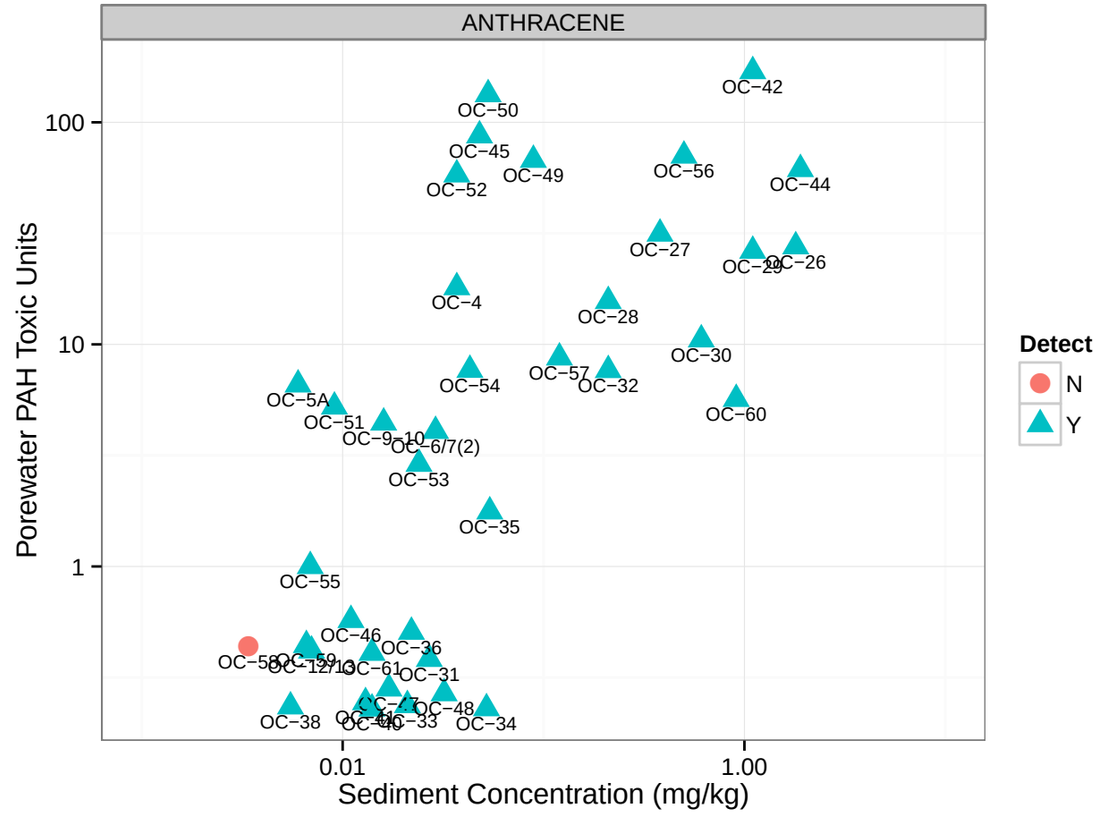

DIESEL RANGE ORGANICS (DRO), TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e+04
1e+06
Sediment Concentration (µg/gOC)
OC−42
OC−45
OC−44
OC−26
OC−29
OC−27
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9_10
OC−6/7(2)
OC−35
OC−46
OC−36
OC−31
OC−12/13
OC−41
OC−38
OC−34
Detect
N
Y

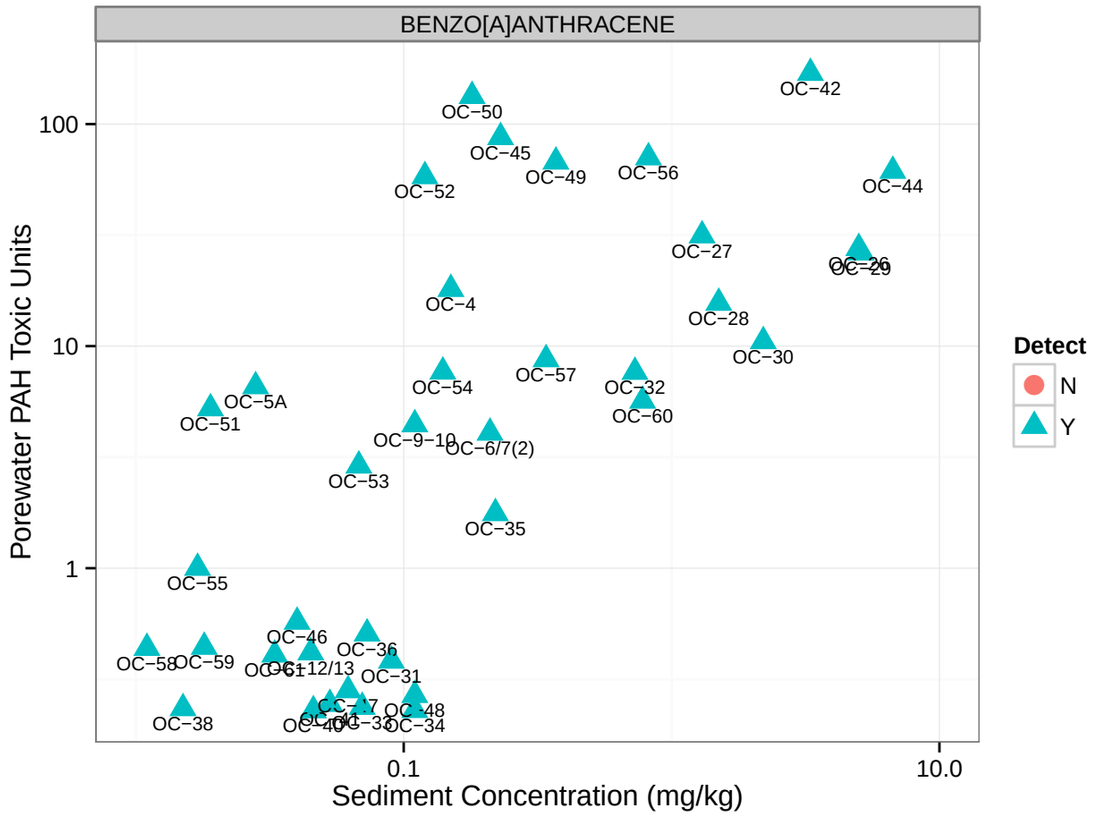

RESIDUAL RANGE ORGANICS (RRO)
Porewater PAH Toxic Units
100
10
1
100
10000
Sediment Concentration (mg/kg)
OC−42
OC−45
OC−44
OC−26
OC−29
OC−27
OC−4
OC−28
OC−30
OC−32
OC−5A
OC−9_10
OC−6/7(2)
OC−35
OC−46
OC−36
OC−31
OC−12/13
OC−38
OC−40
OC−33
Detect
N
Y

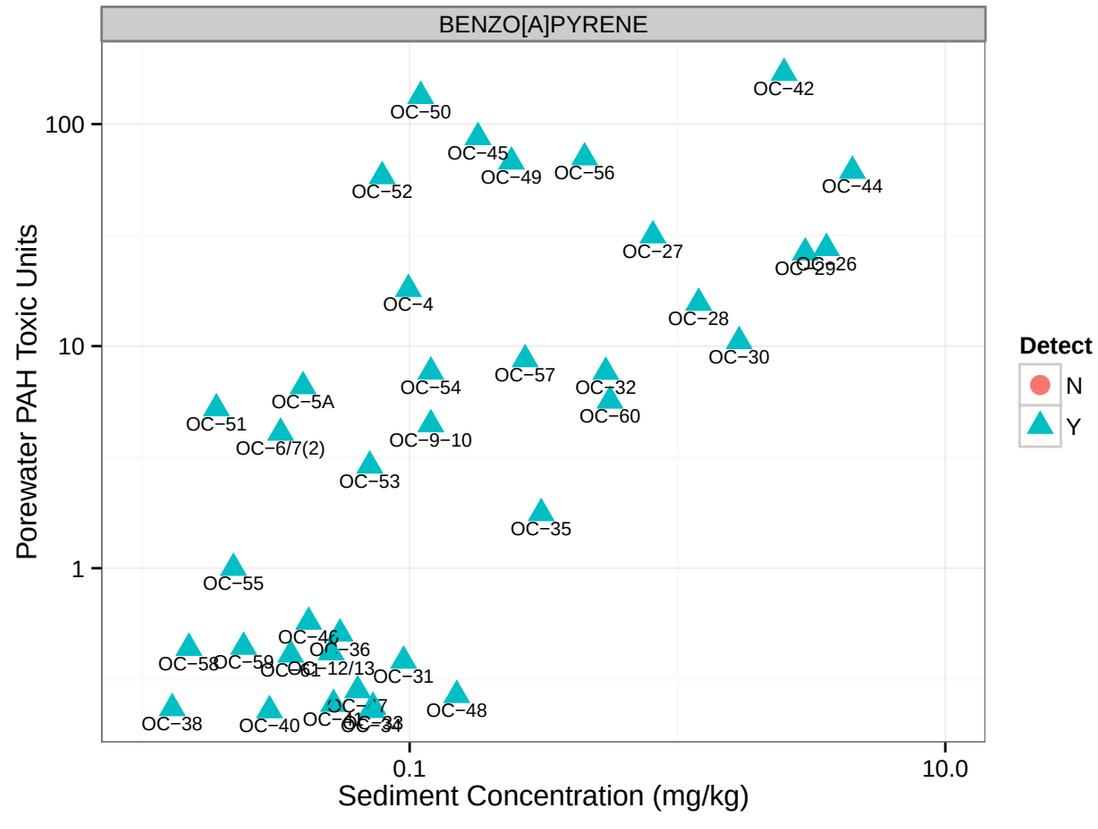

RESIDUAL RANGE ORGANICS (RRO), TOC−normalized
Porewater PAH Toxic Units
100
10
1
1e+04
1e+06
Sediment Concentration (µg/gOC)
OC−42
OC−45
OC−44
OC−26
OC−29
OC−27
OC−4
OC−28
OC−30
OC−5A
OC−6/7(2)
OC−35
OC−46
OC−36
OC−31
OC−12/13
OC−34
Detect
N
Y

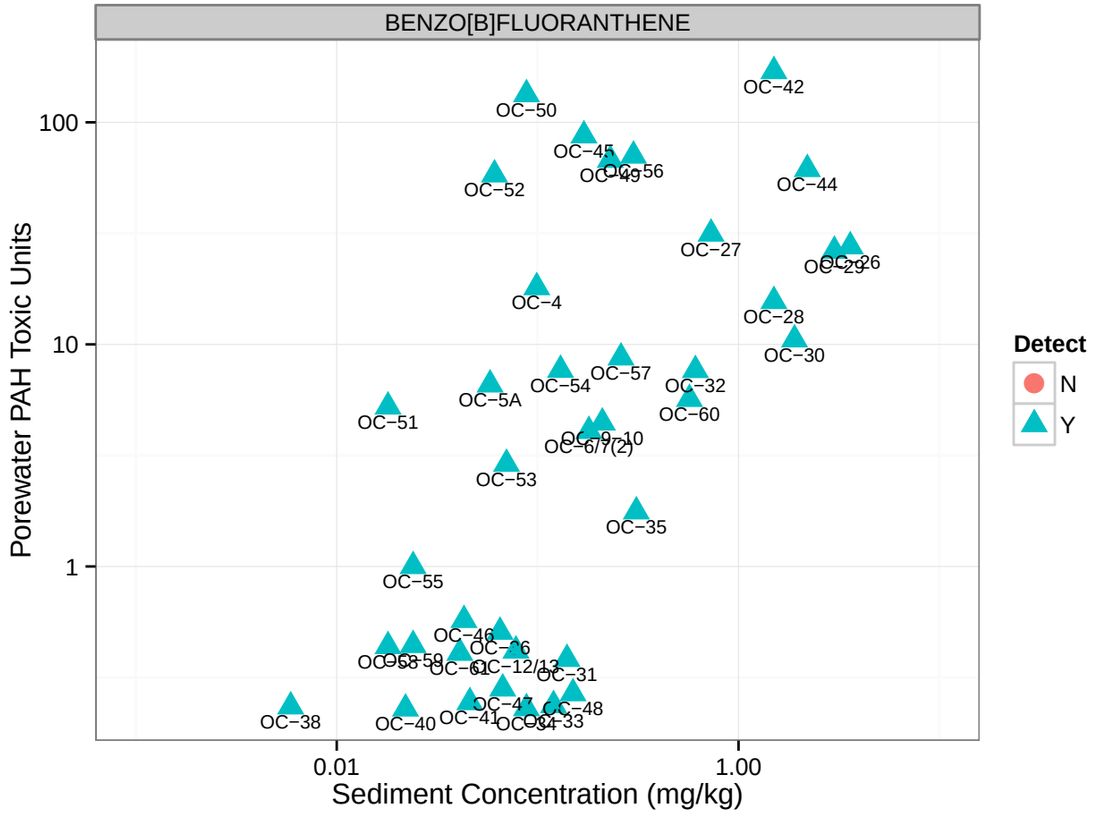

ACENAPHTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−49
OC−52
OC−45
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−32
OC−57
OC−54
OC−5A
OC−51
OC−9−10
OC−60
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−38
OC−40
OC−33
OC−34
Detect
N
Y

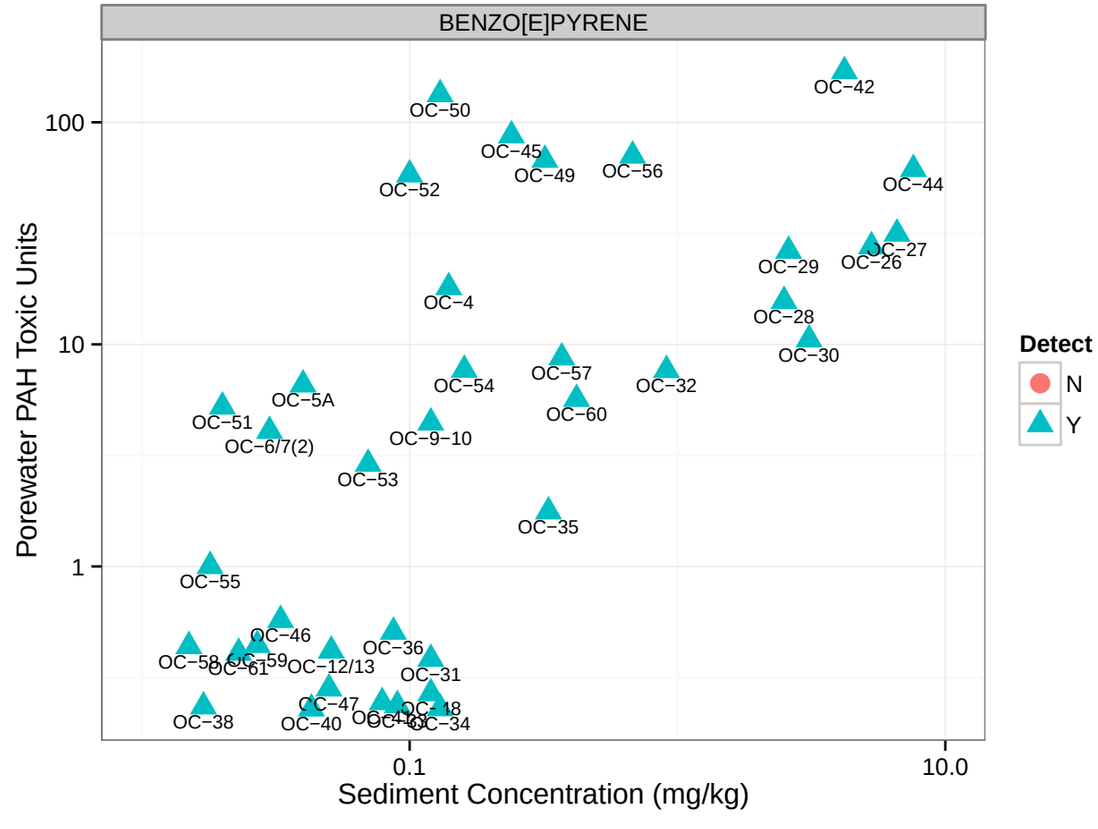

ACENAPHTHYLENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−56
OC−19
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−61
OC−31
OC−47
OC−48
OC−33
Detect
N
Y

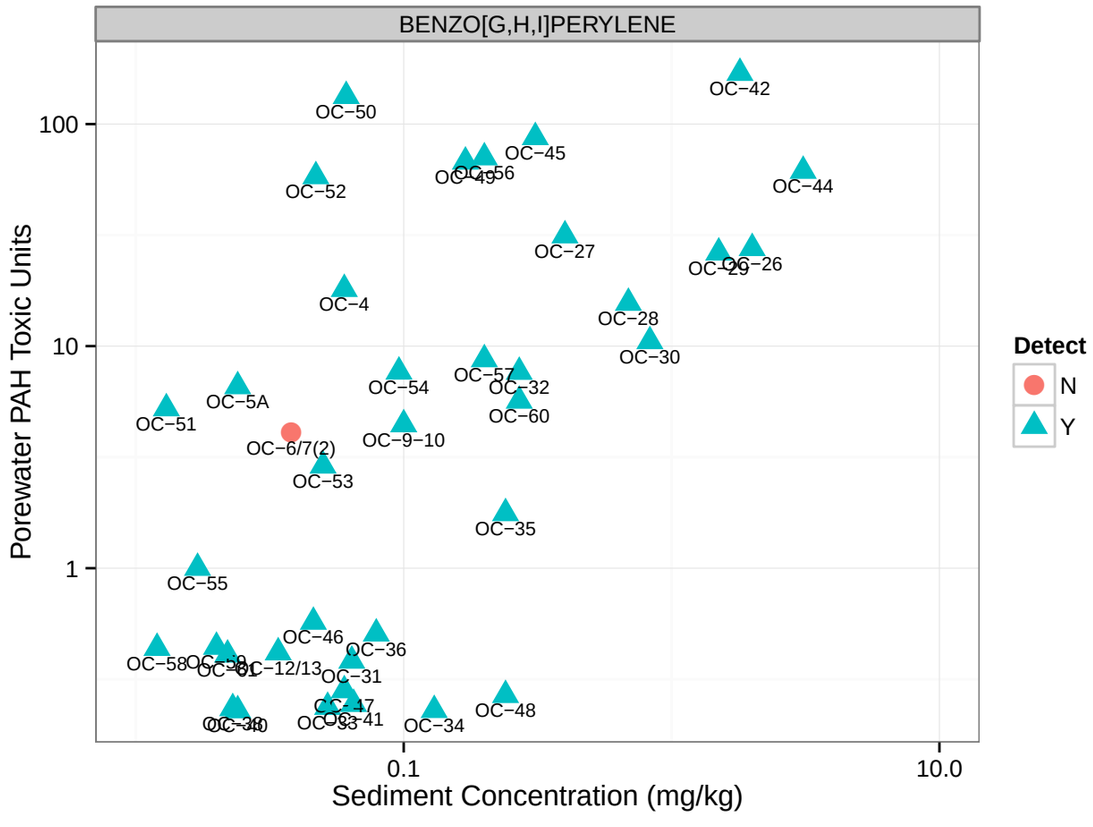

ANTHRACENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−61
OC−31
OC−47
OC−48
OC−38
OC−40
OC−33
OC−34
Detect
N
Y

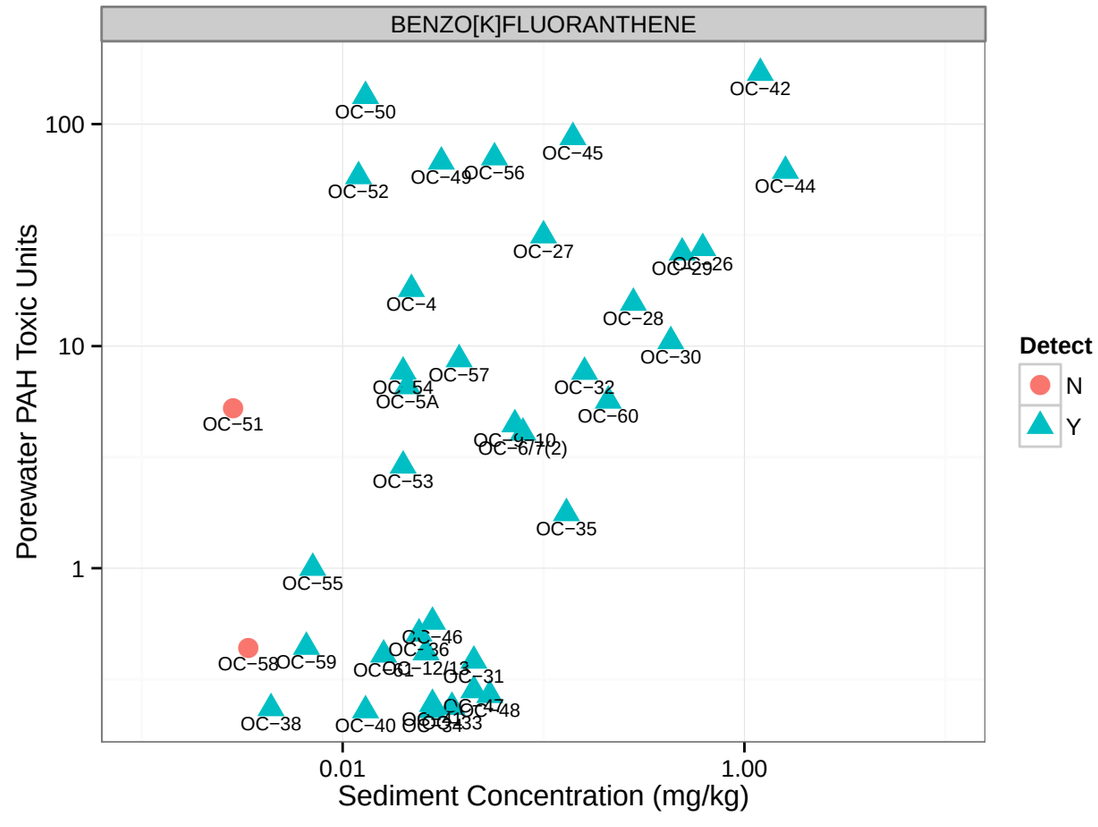

BENZO[A]ANTHRACENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−38
OC−48
OC−34
Detect
N
Y

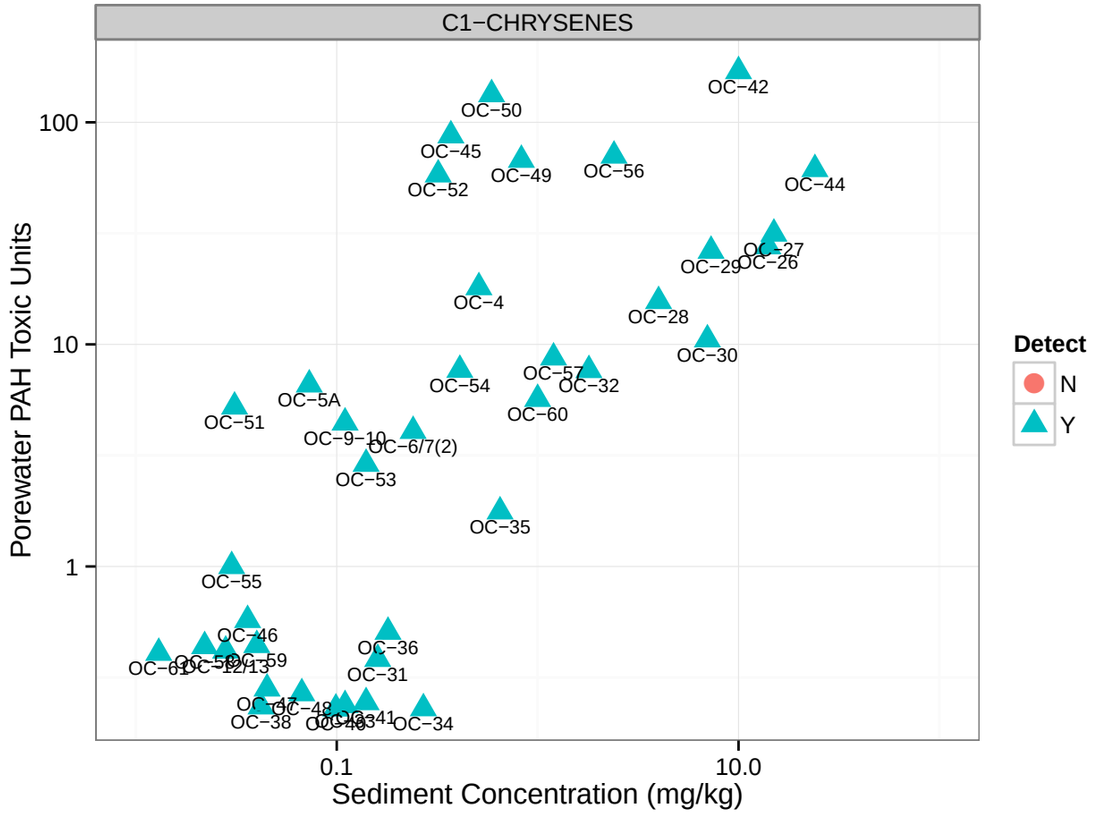

BENZO[A]PYRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−6/7(2)
OC−9−10
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

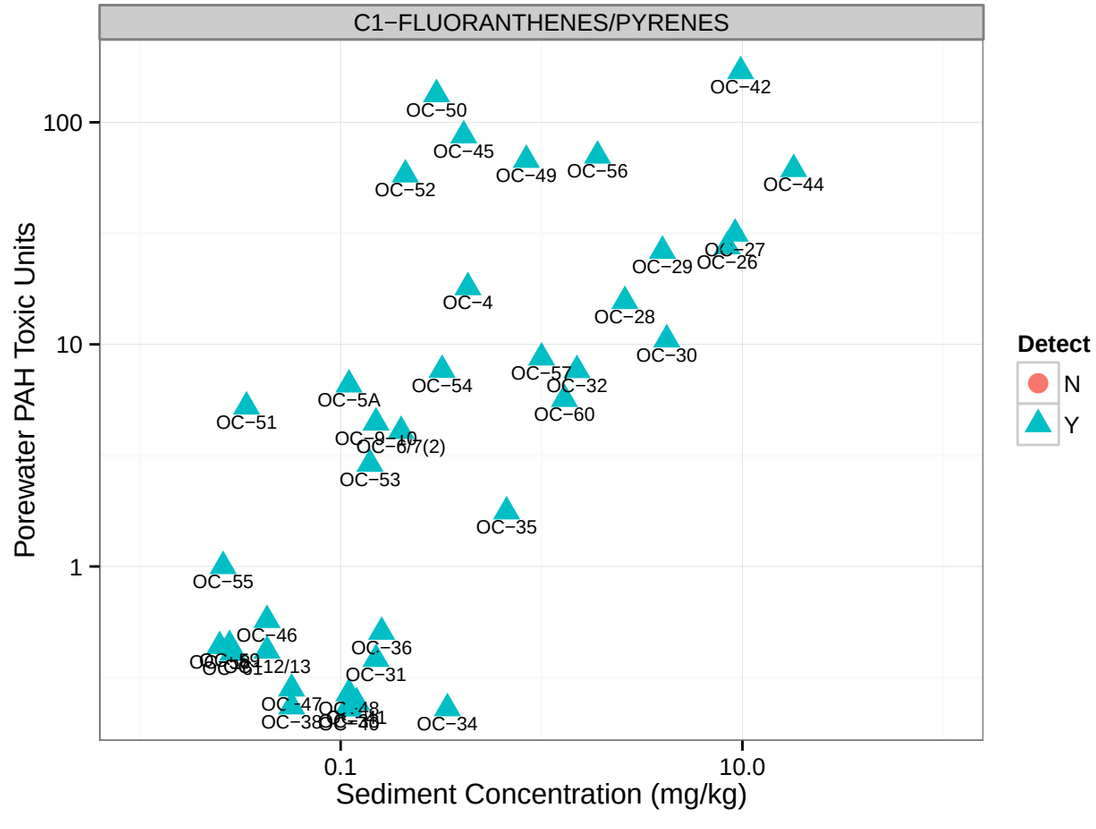

BENZO[B]FLUORANTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−48
OC−38
OC−40
OC−41
OC−34
Detect
N
Y

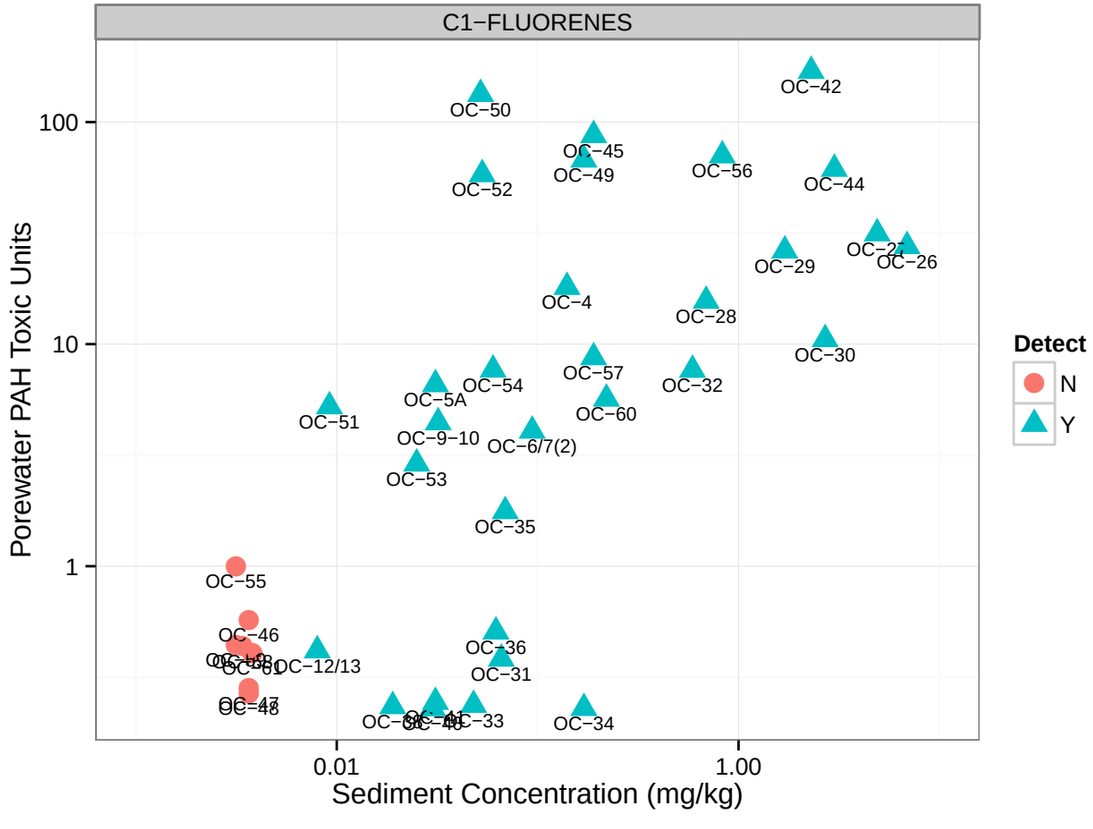

BENZO[E]PYRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−29
OC−27
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

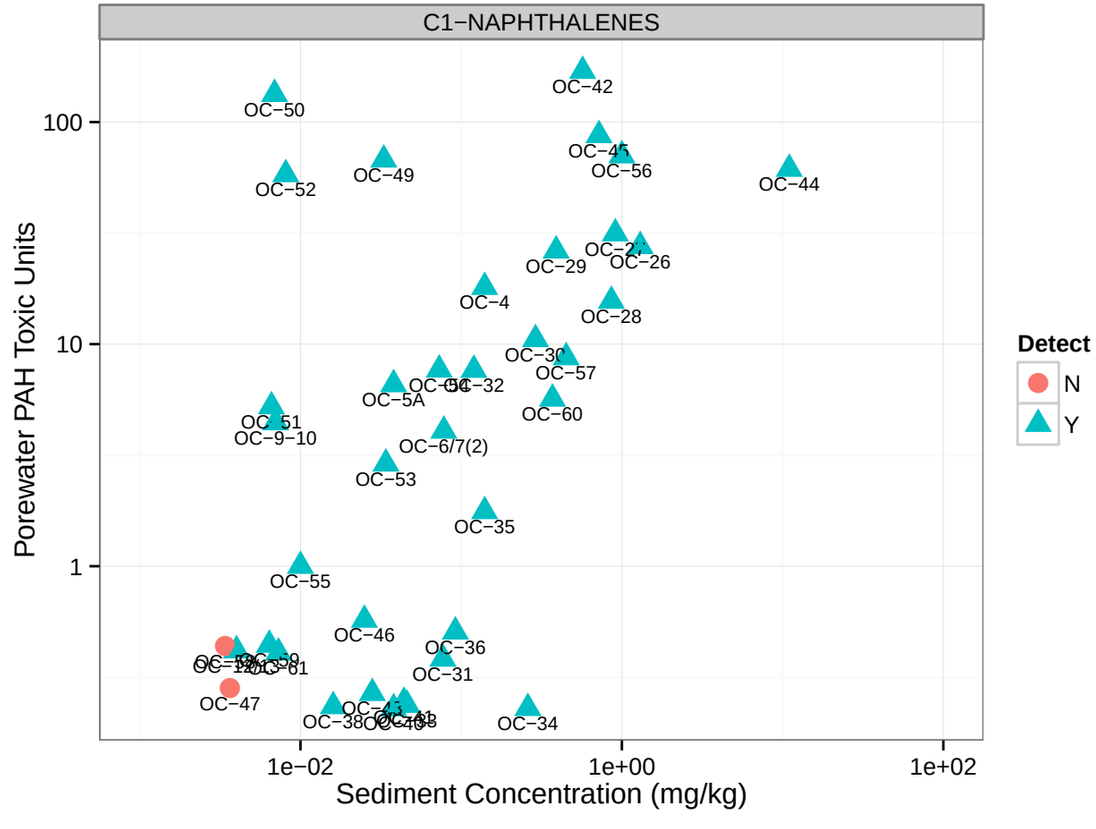

BENZO[G,H,I]PERYLENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−12/13
OC−31
OC−48
OC−34
Detect
N
Y

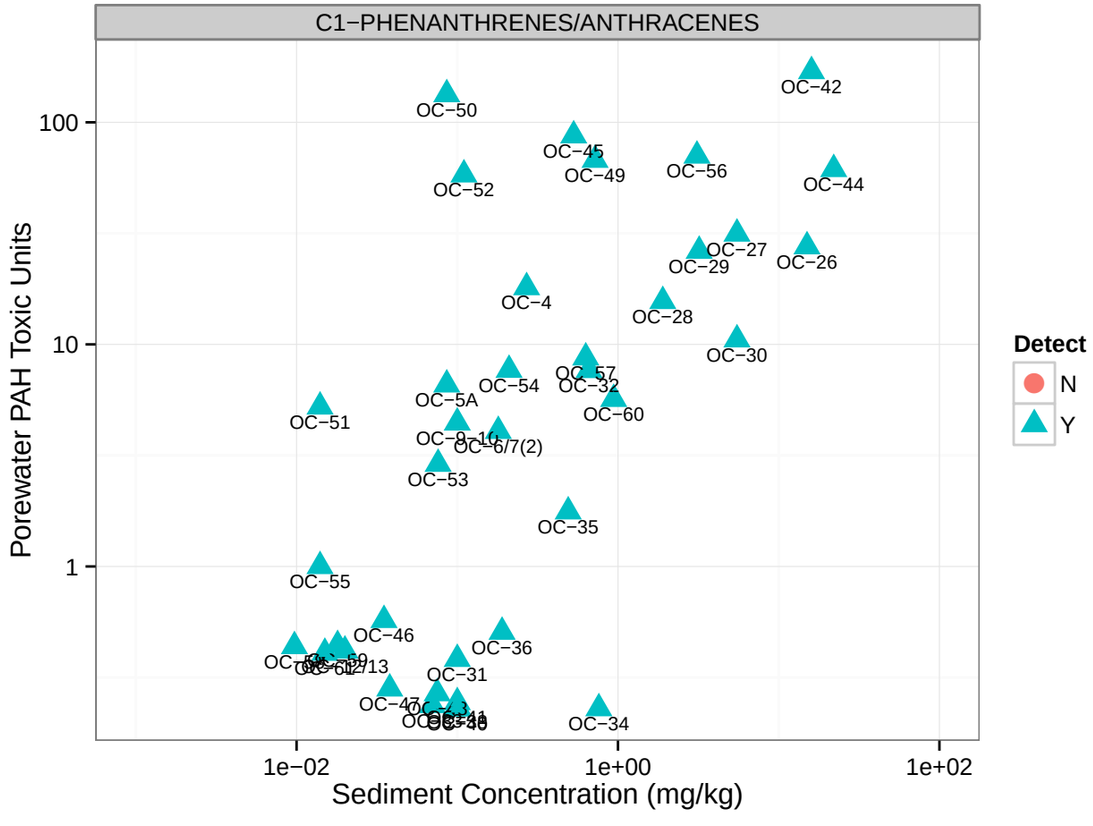

BENZO[K]FLUORANTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

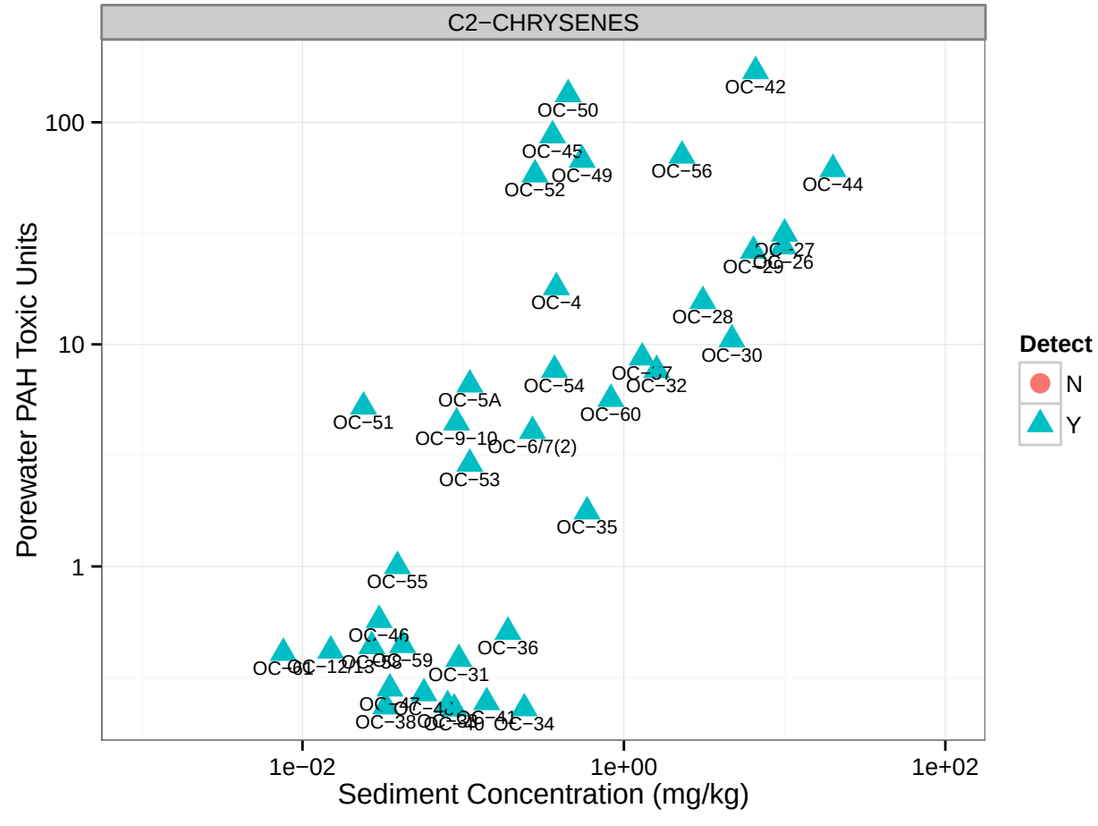

C1−CHRYSENES
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−34
Detect
N
Y

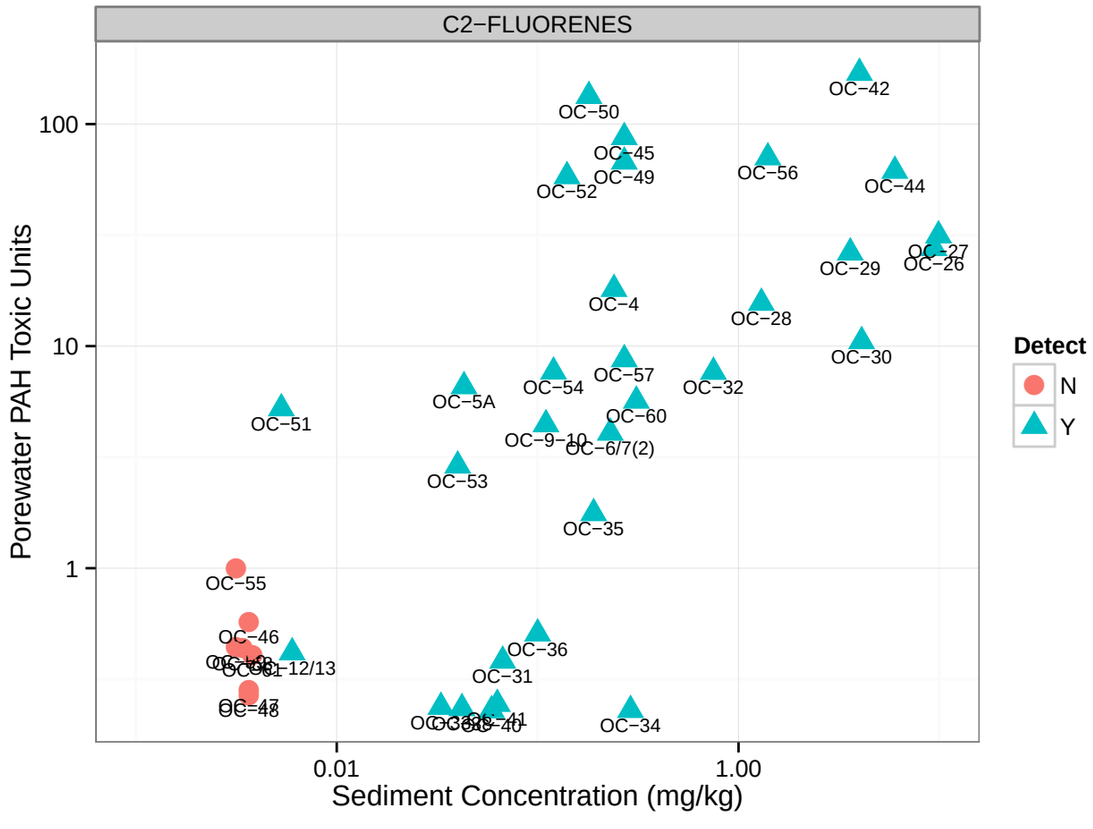

C1−FLUORANTHENES/PYRENES
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−47
OC−34
Detect
N
Y

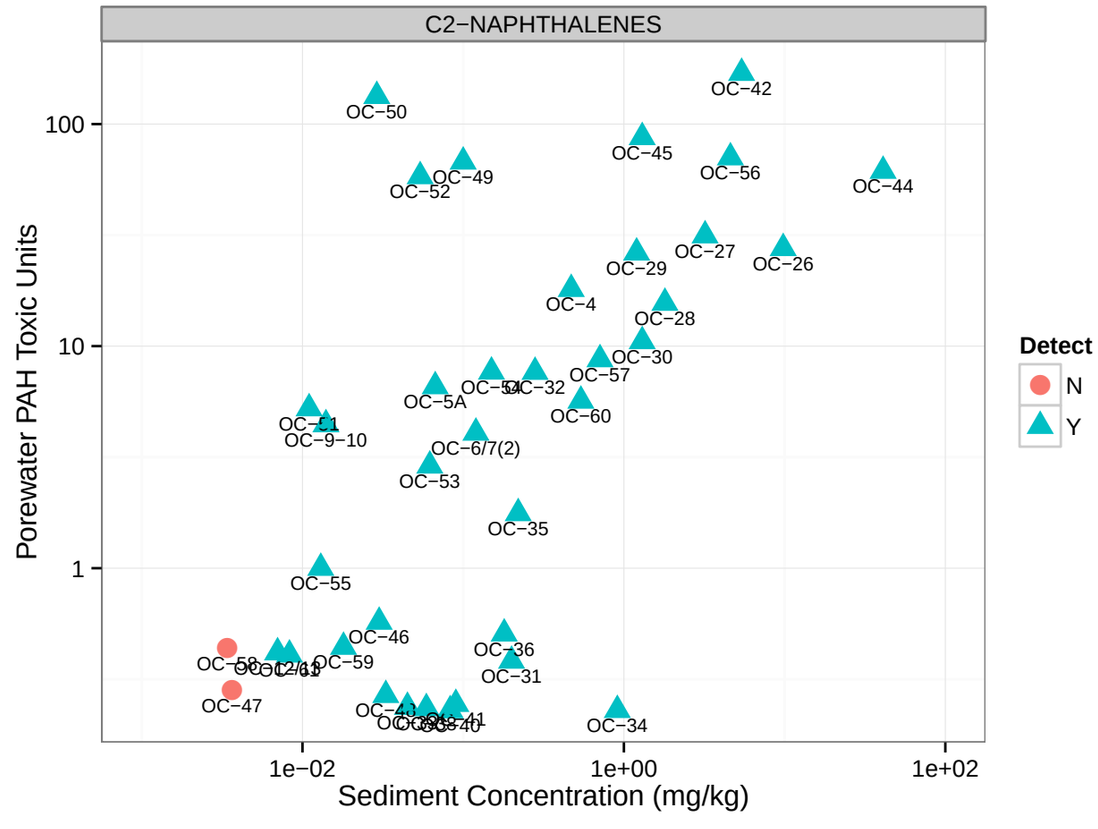

C1−FLUORENES
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−34
Detect
N
Y

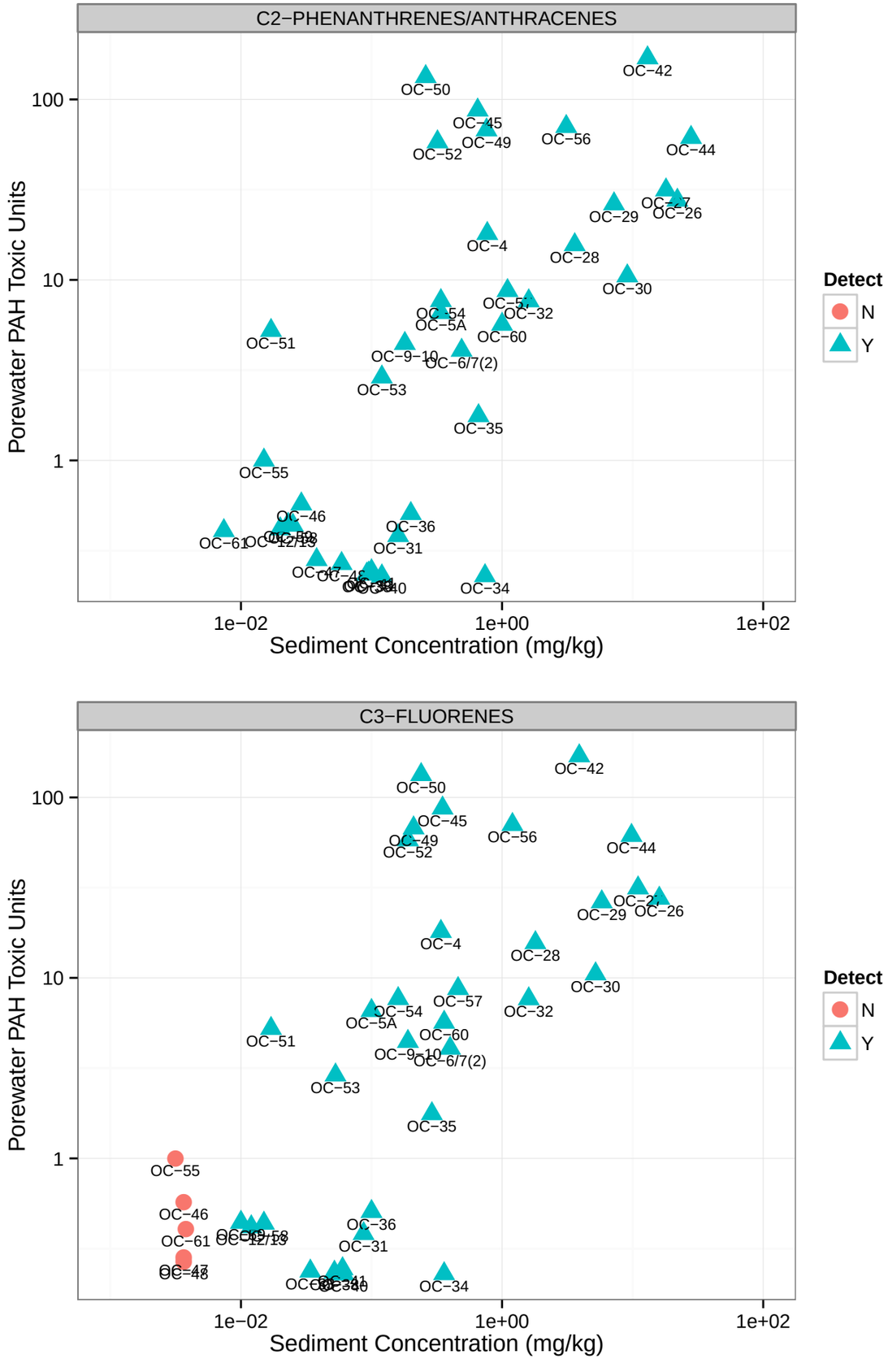

C1−NAPHTHALENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−52
OC−49
OC−45
OC−56
OC−44
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−31
OC−47
OC−34
Detect
N
Y

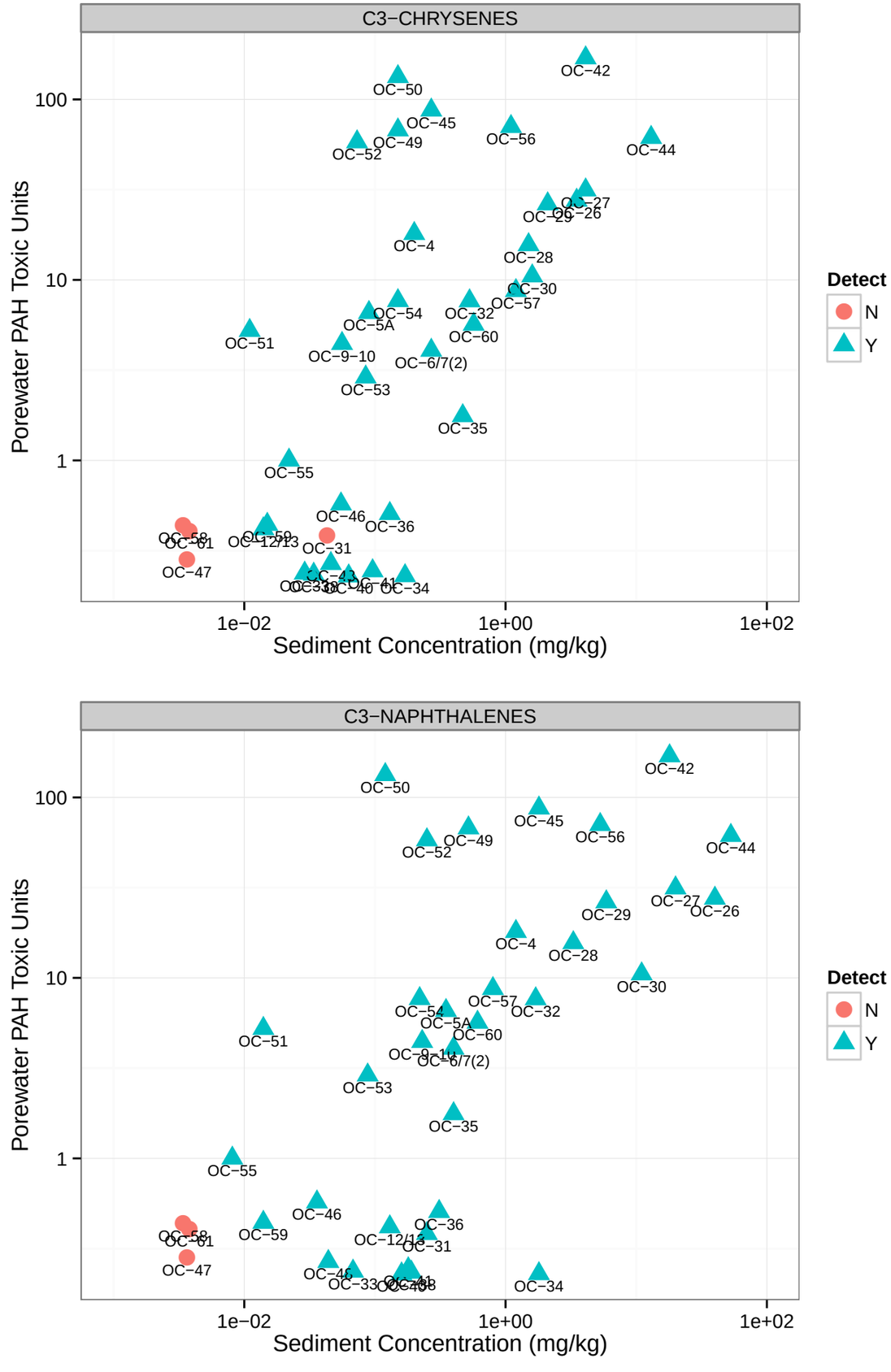

C1−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−31
OC−34
Detect
N
Y


C2−CHRYSENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−31
OC−34
Detect
N
Y


C2−FLUORENES
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−31
OC−34
Detect
N
Y

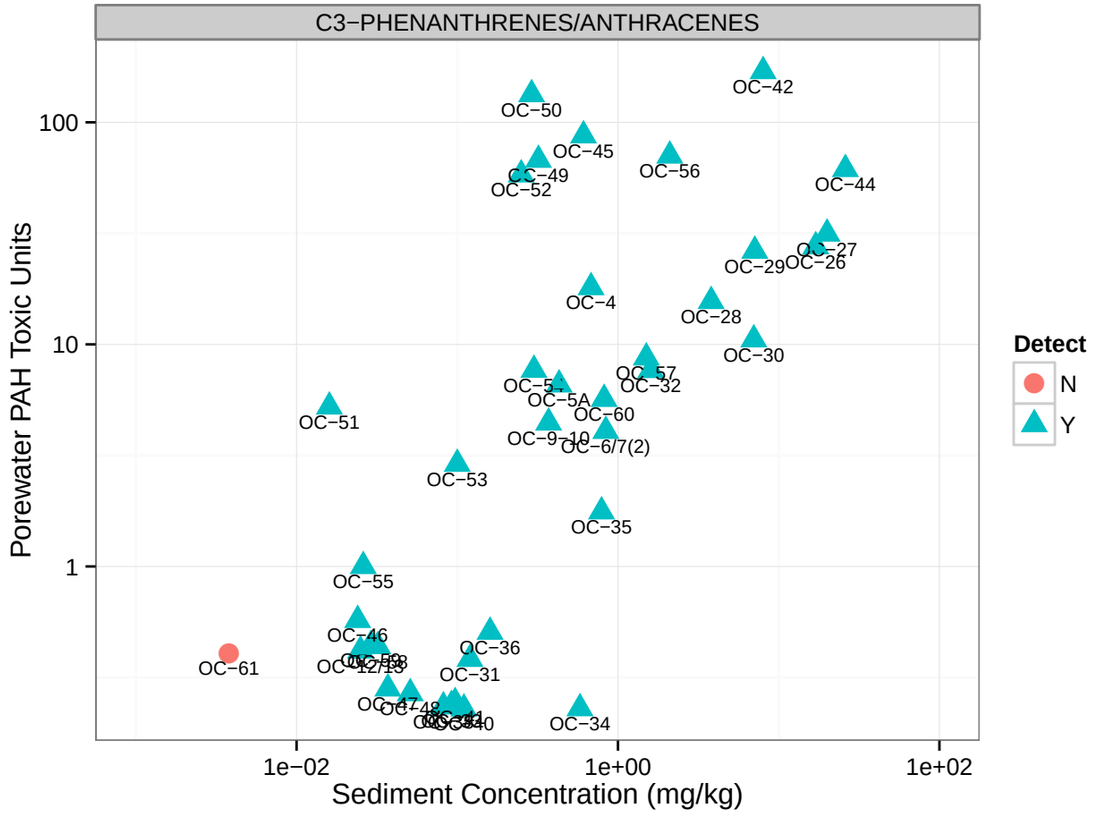

C2−NAPHTHALENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−31
OC−47
OC−34
Detect
N
Y

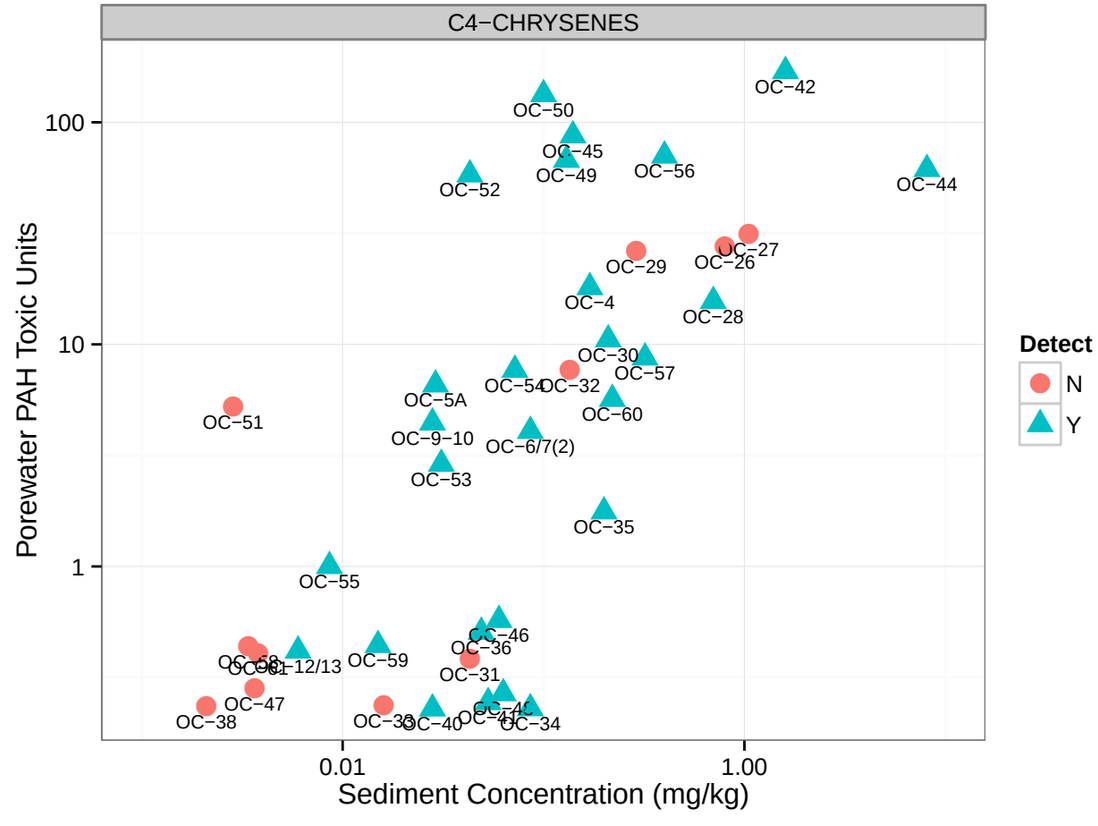

C2−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y

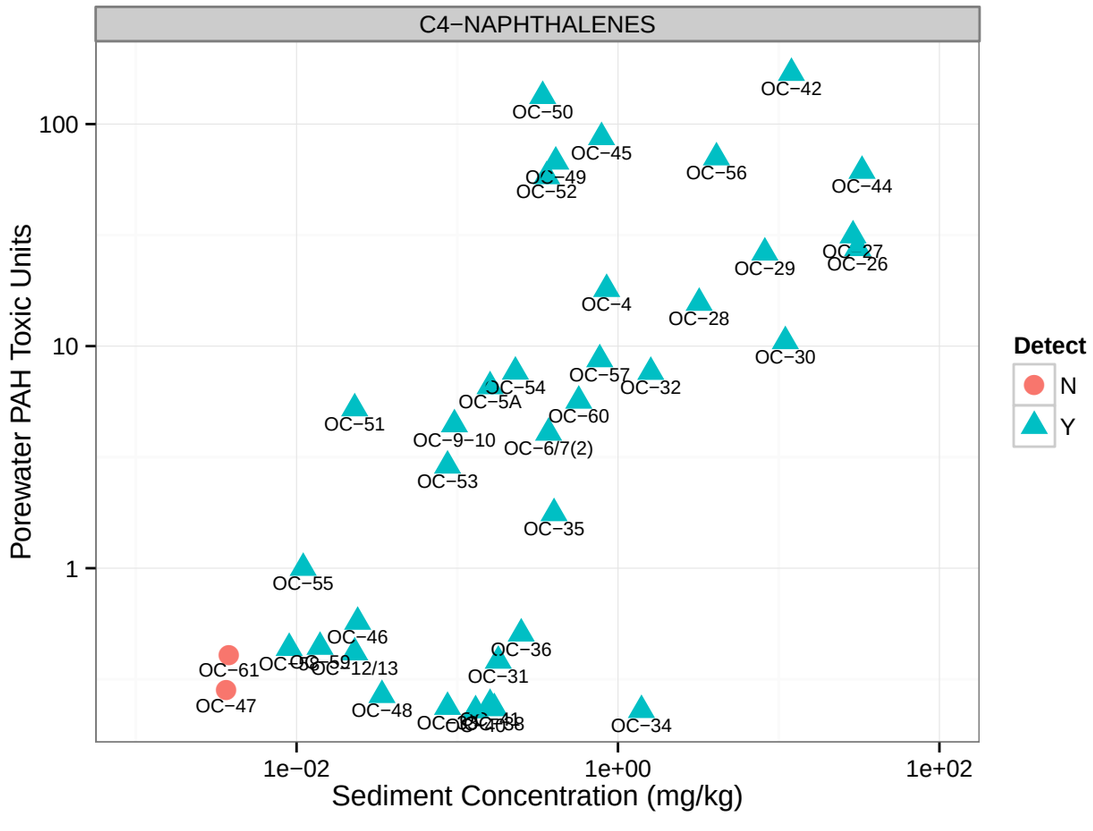

C3−CHRYSENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y

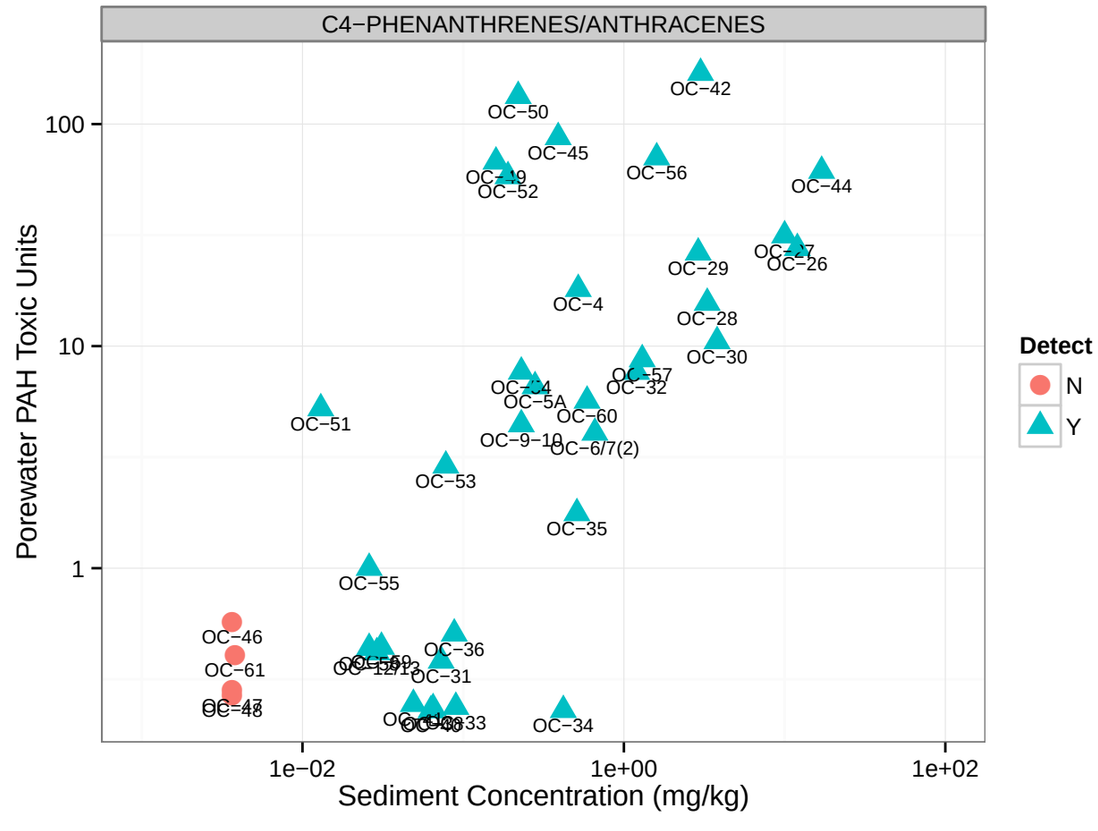
C3−FLUORENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y

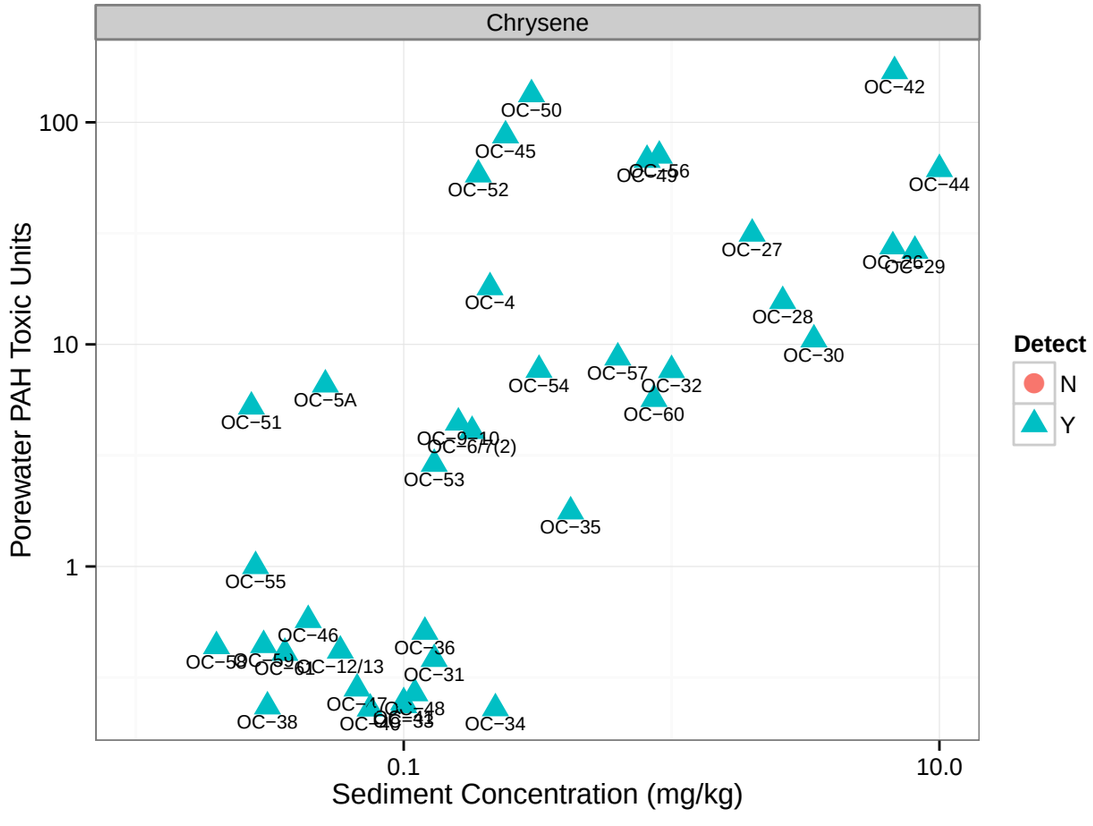
C3−NAPHTHALENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
Detect
N
Y

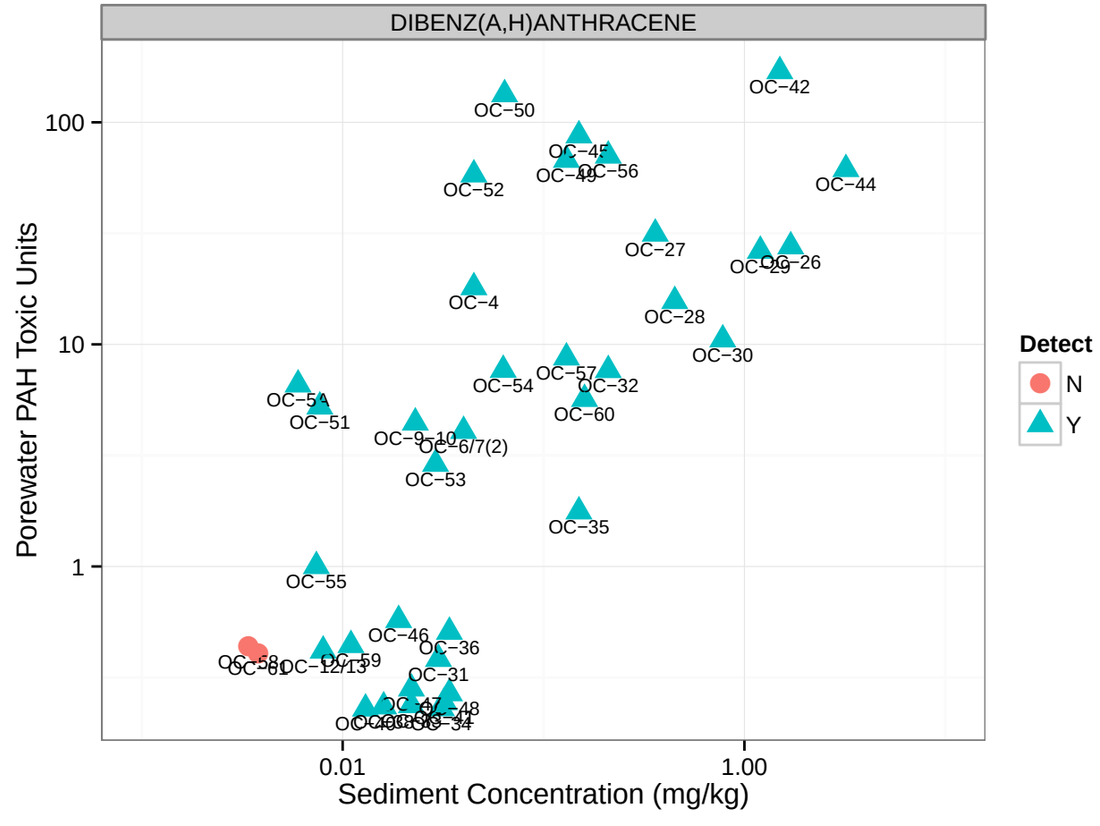

C3−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−34
Detect
N
Y

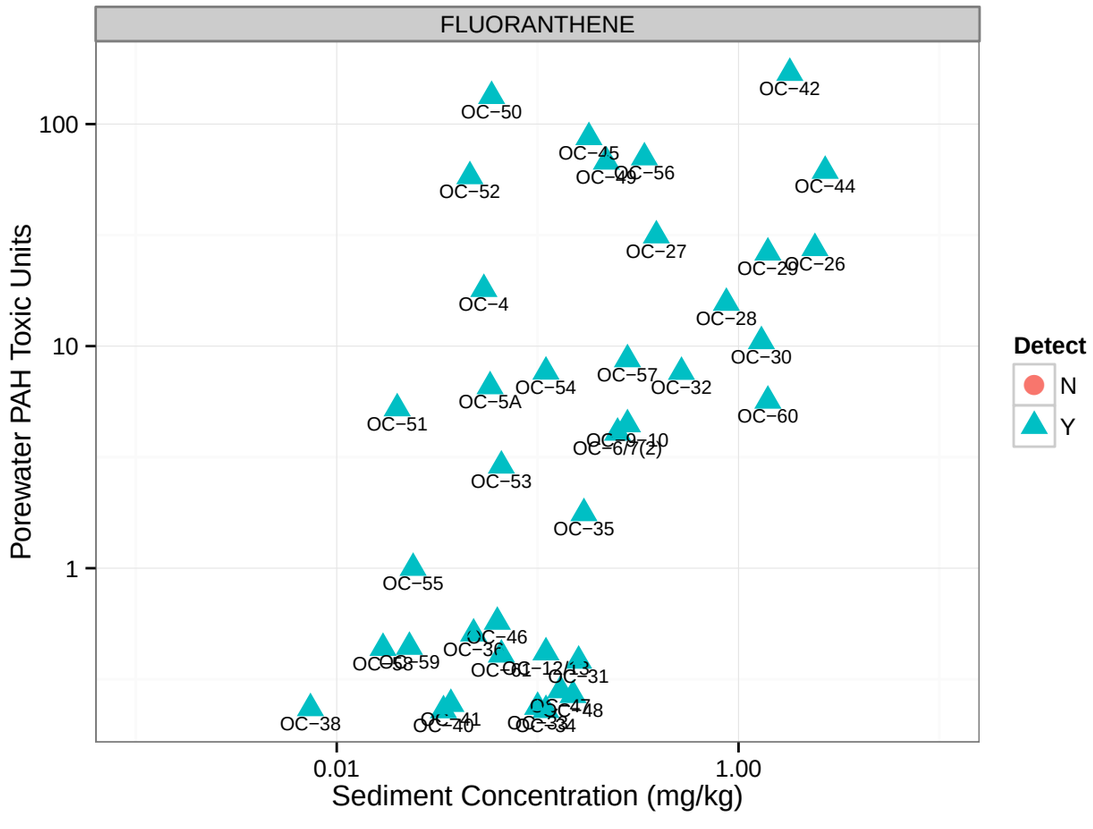

C4−CHRYSENES
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−12/13
OC−31
OC−47
OC−38
OC−34
Detect
N
Y

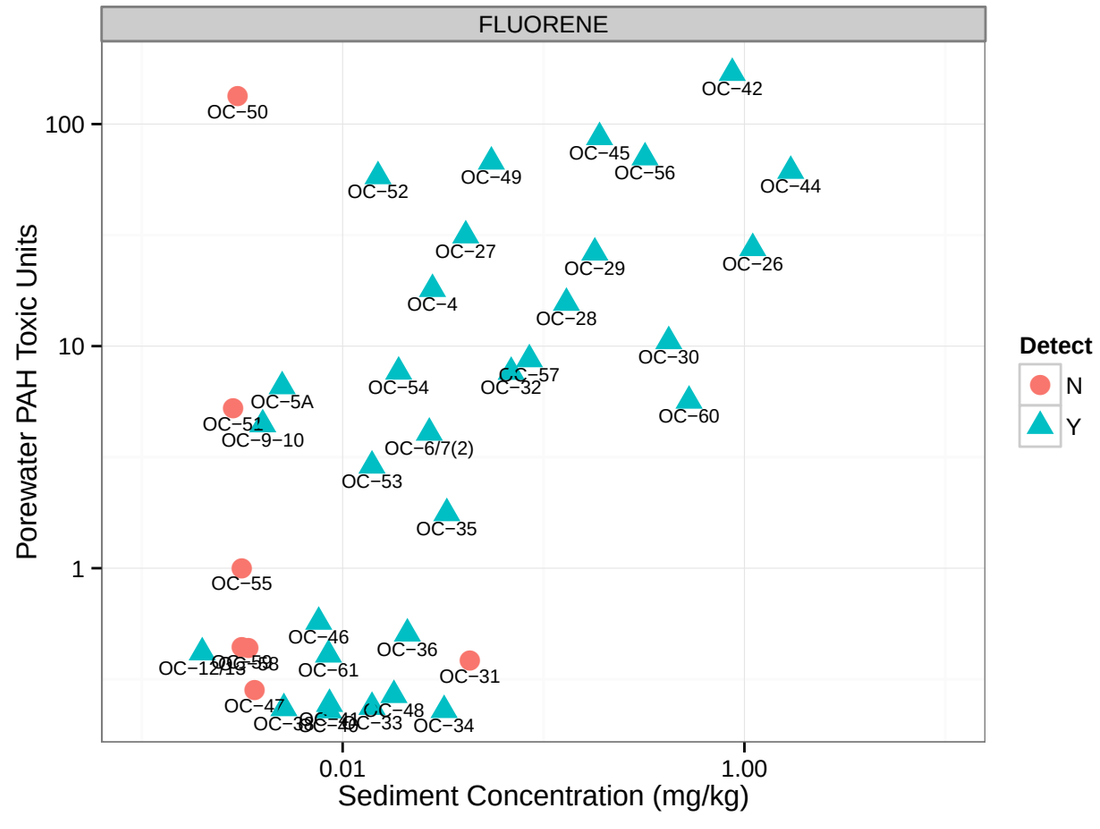

C4−NAPHTHALENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−34
Detect
N
Y

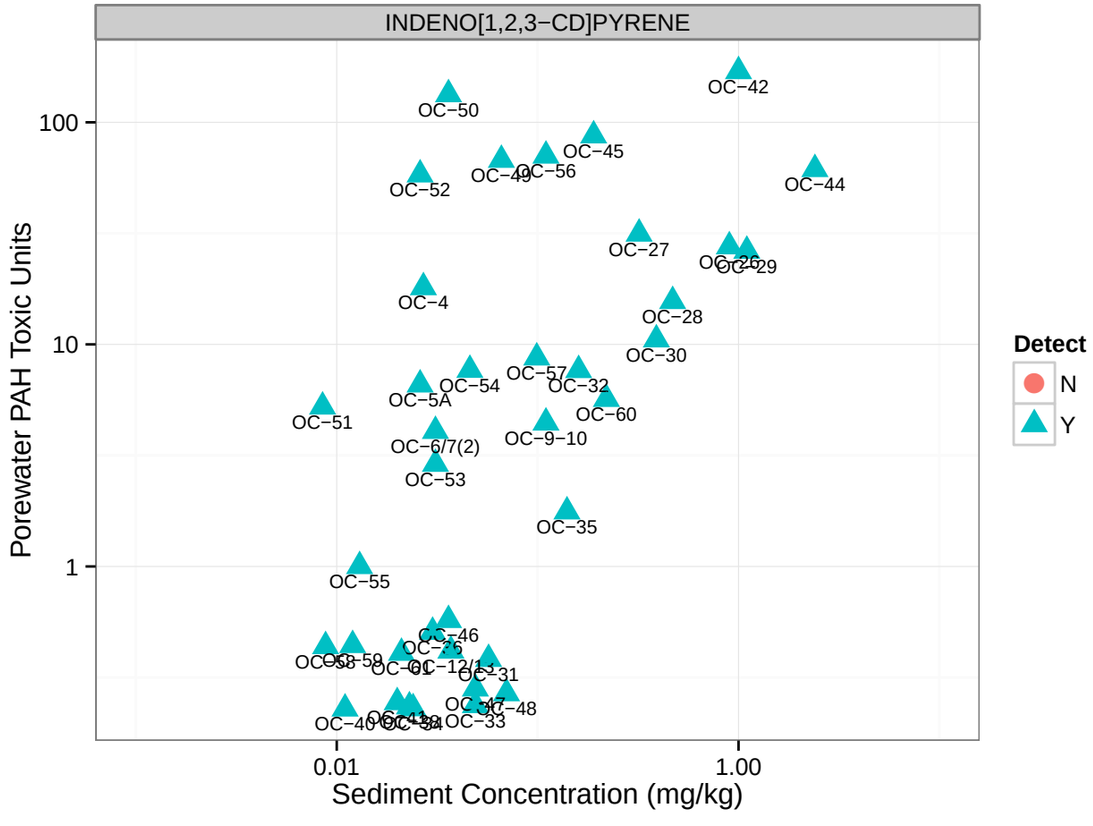

C4−PHENANTHRENES/ANTHRACENES
Porewater PAH Toxic Units
100
10
1
1e−02
1e+00
1e+02
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−34
Detect
N
Y

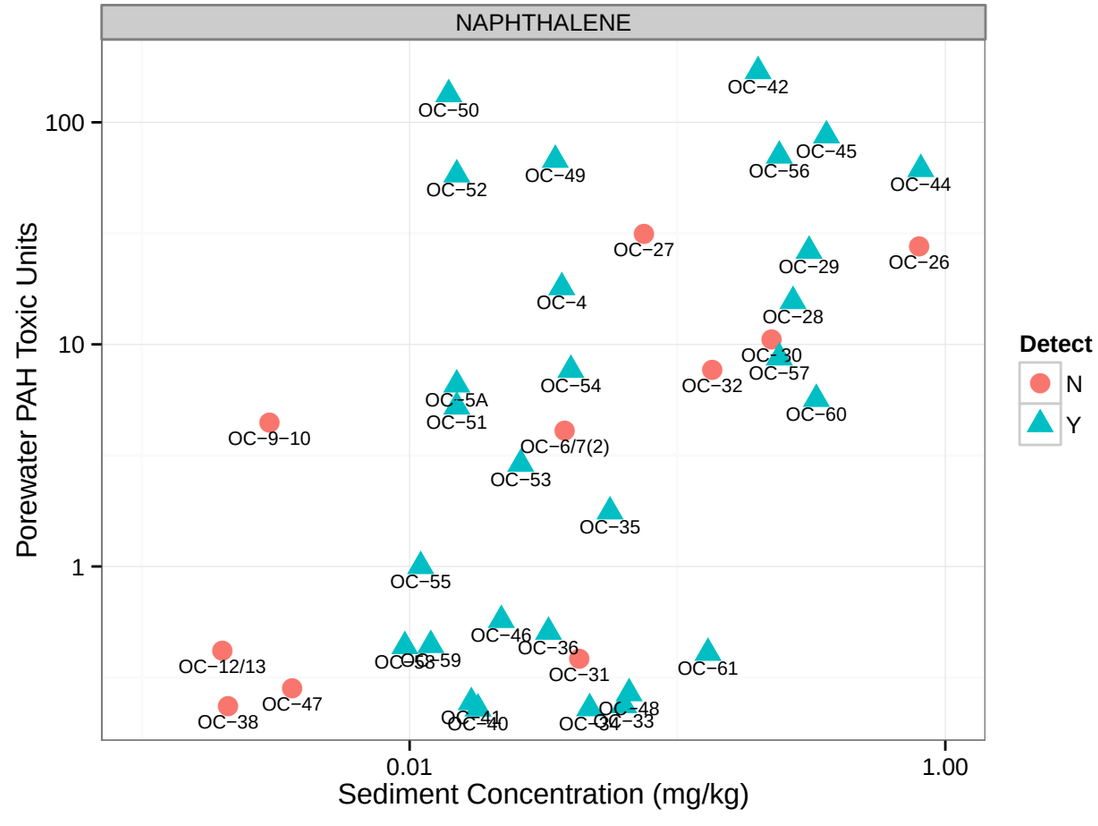

Chrysene
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−27
OC−26
OC−29
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−12/13
OC−31
OC−38
OC−34
Detect
N
Y

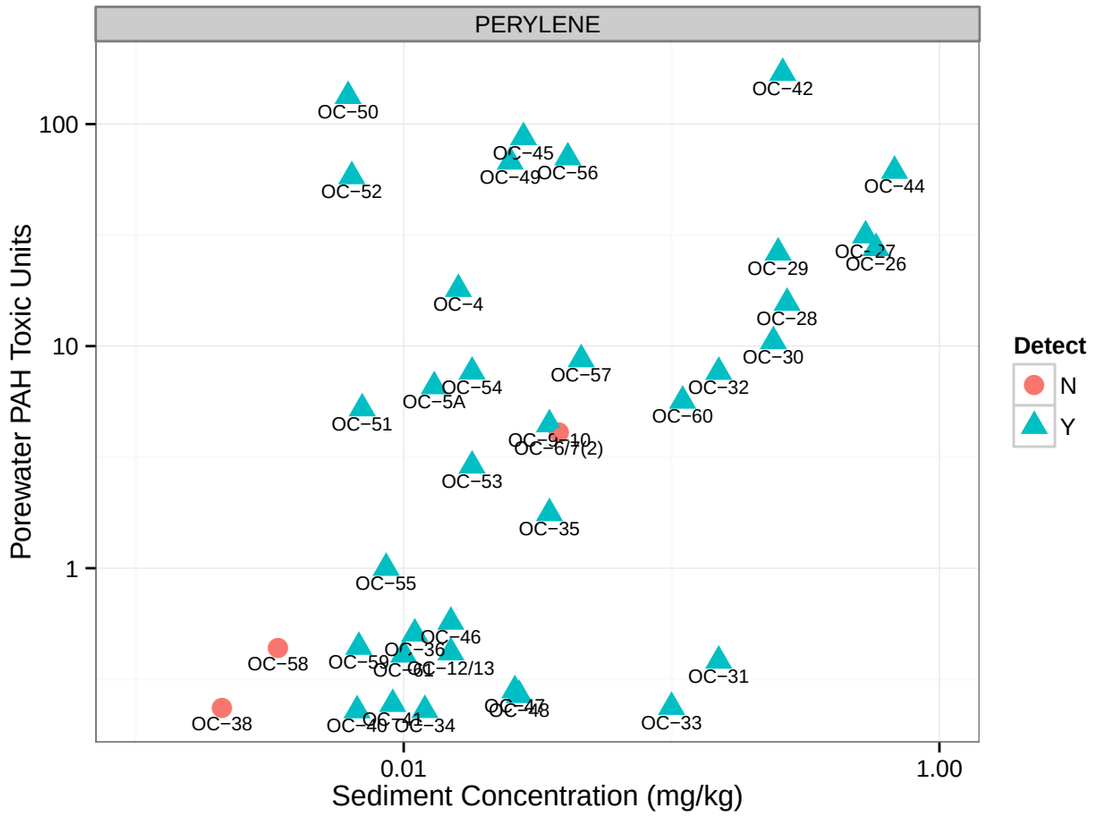

DIBENZ(A,H)ANTHRACENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−27
OC−26
OC−29
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−34
Detect
N
Y

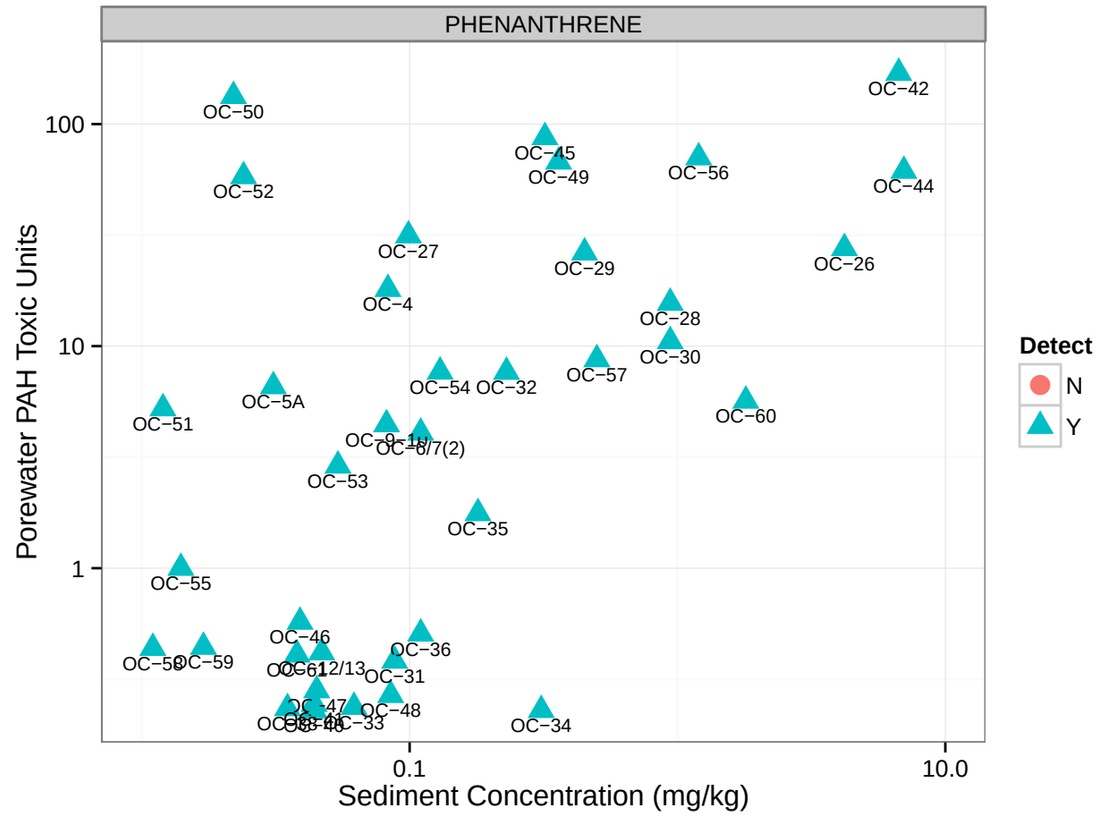

FLUORANTHENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−31
OC−38
OC−34
Detect
N
Y

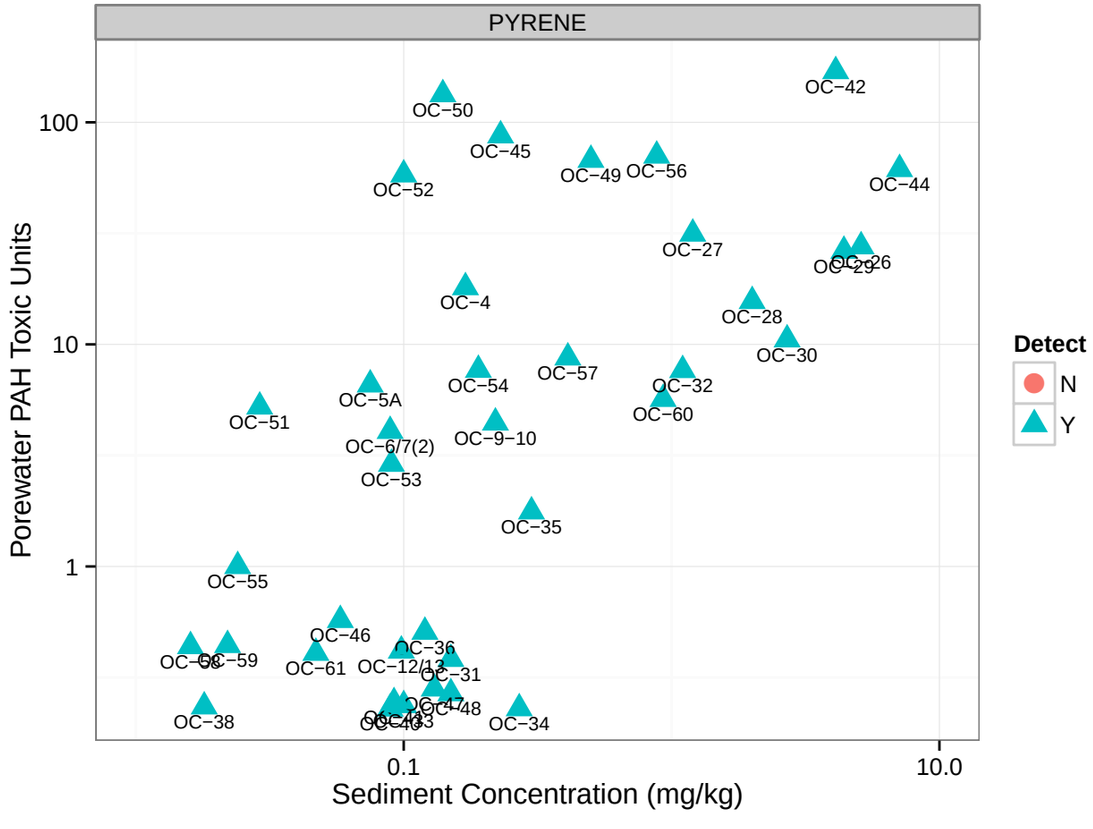

FLUORENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−52
OC−49
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−34
Detect
N
Y

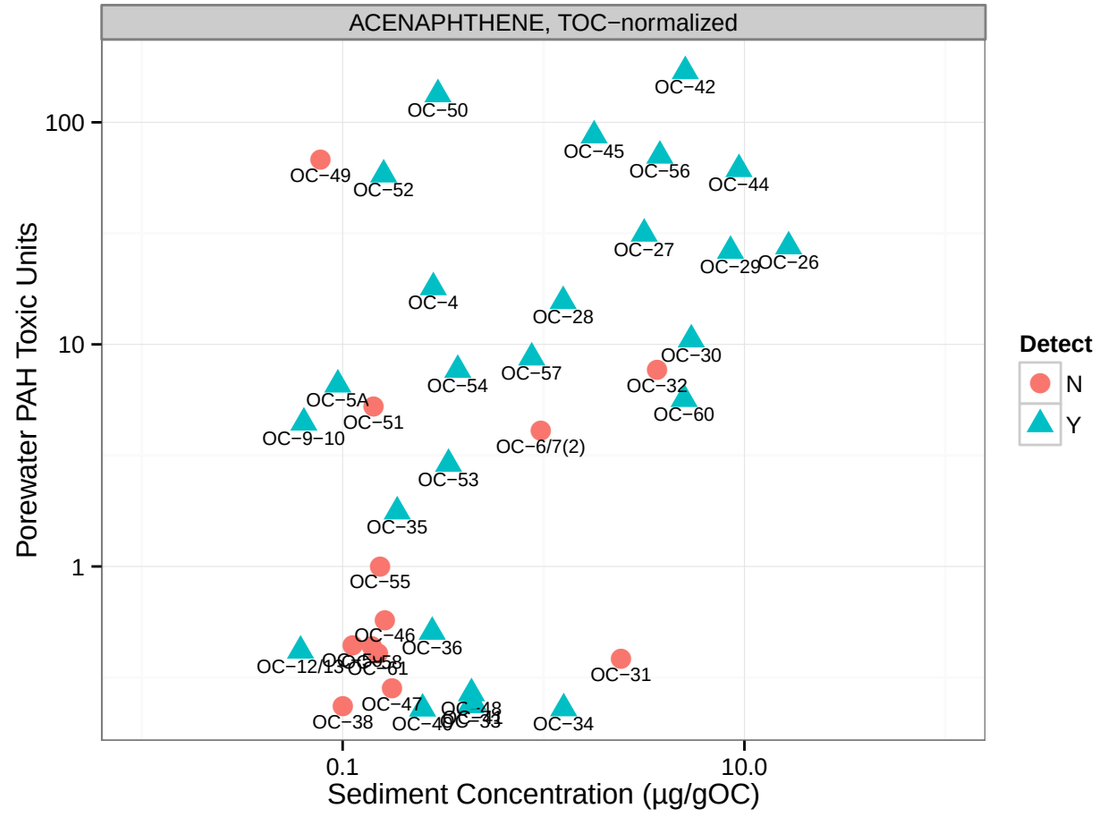

INDENO[1,2,3−CD]PYRENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−52
OC−44
OC−27
OC−25
OC−29
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−41
OC−34
OC−33
Detect
N
Y

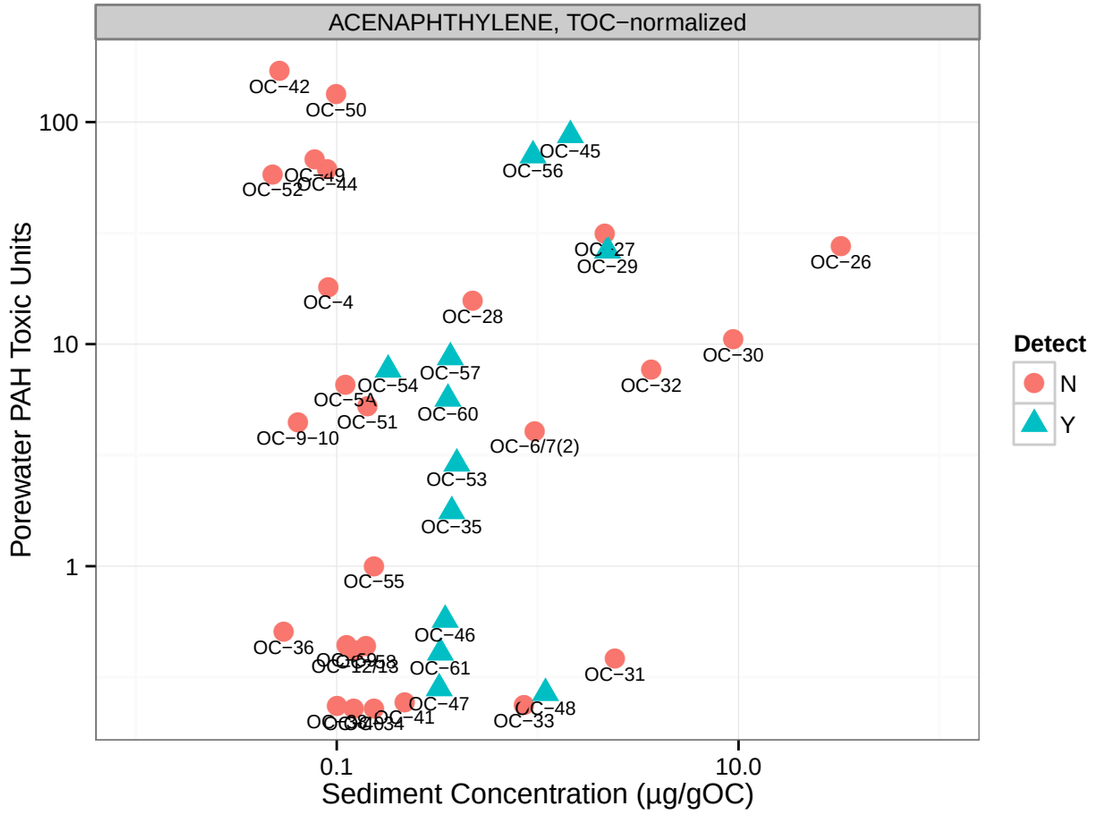

NAPHTHALENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−61
OC−47
OC−48
OC−38
OC−40
OC−41
OC−34
OC−33
Detect
N
Y

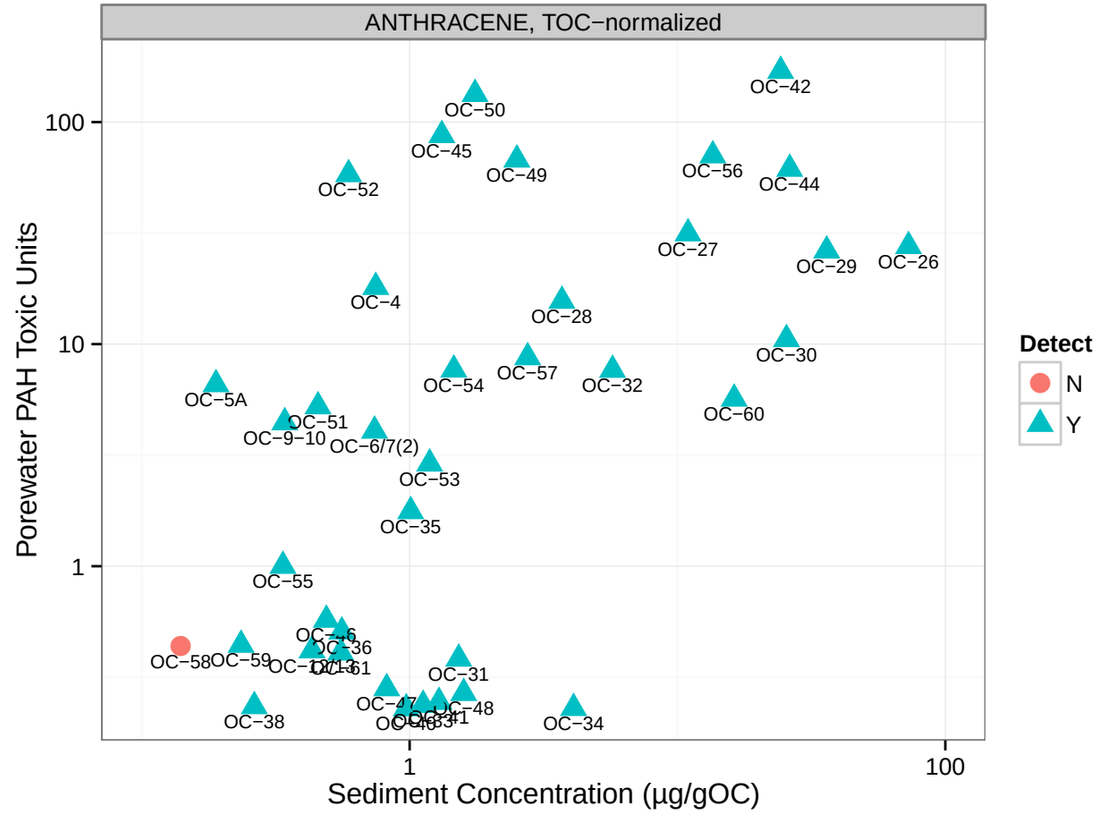

PERYLENE
Porewater PAH Toxic Units
100
10
1
0.01
1.00
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−52
OC−44
OC−27
OC−26
OC−29
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−41
OC−34
OC−33
Detect
N
Y

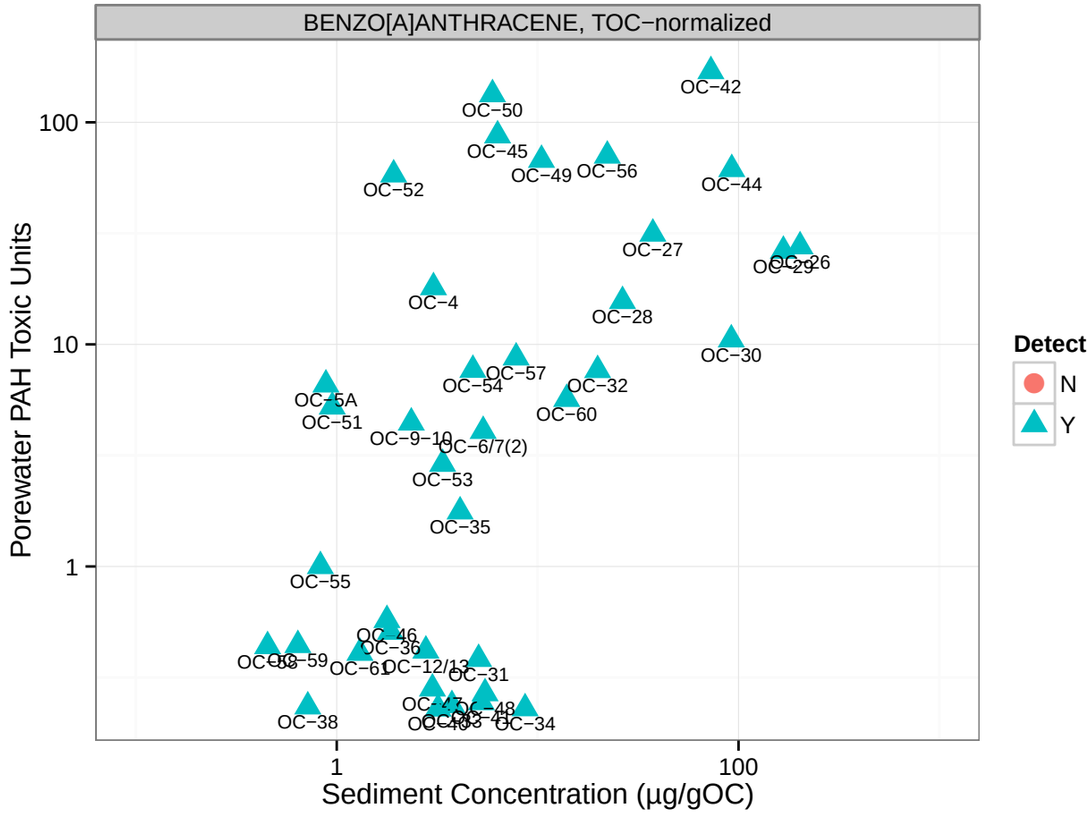

PHENANTHRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−34
OC−33
Detect
N
Y

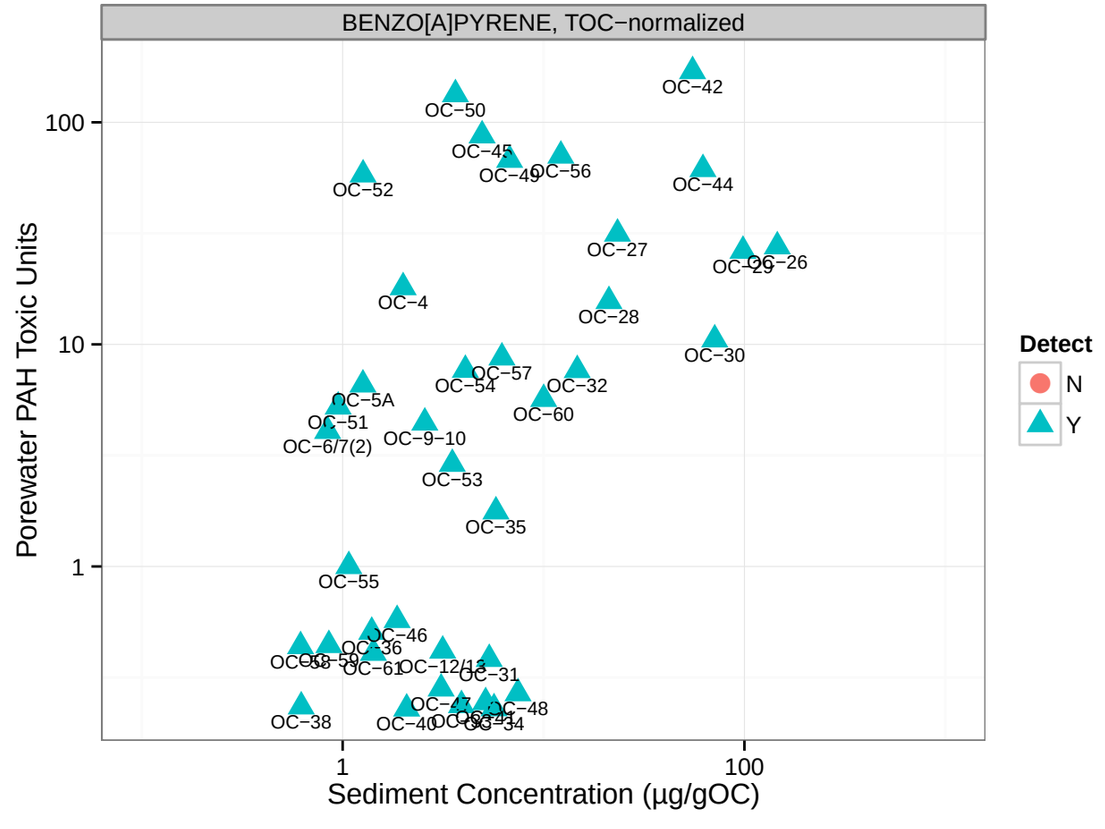

PYRENE
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (mg/kg)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−34
Detect
N
Y

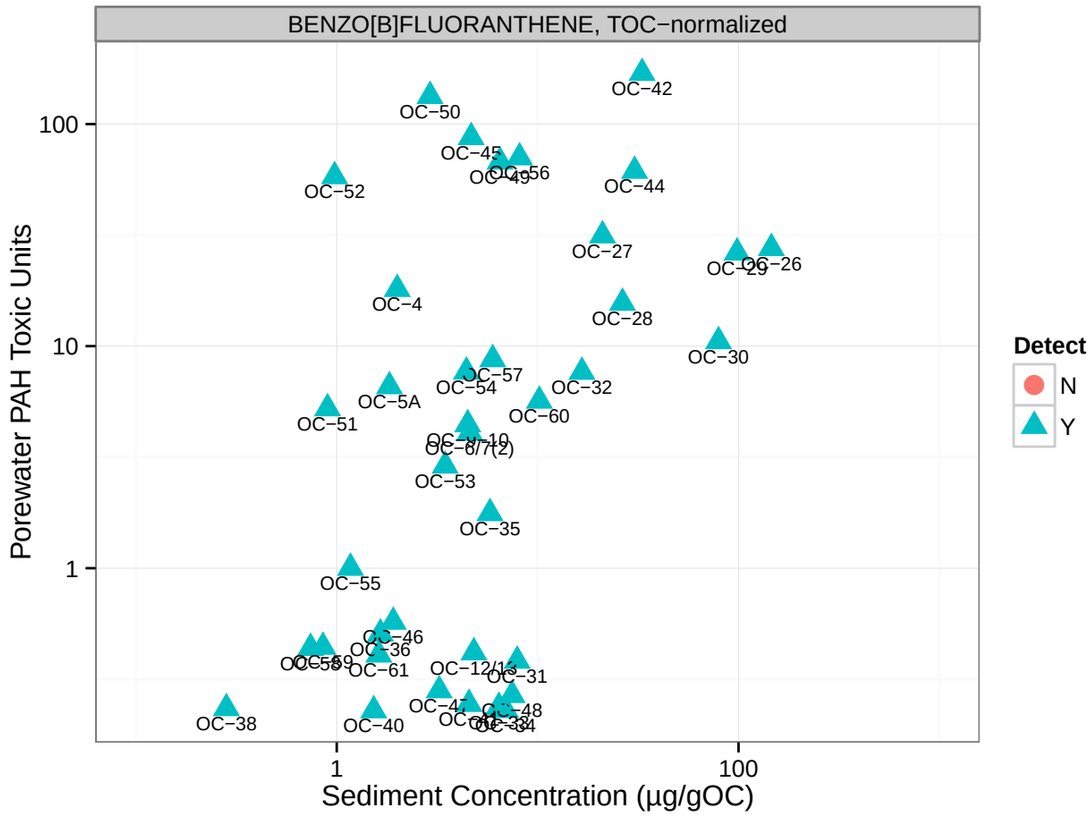

ACENAPHTHENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−31
OC−38
OC−34
Detect
N
Y

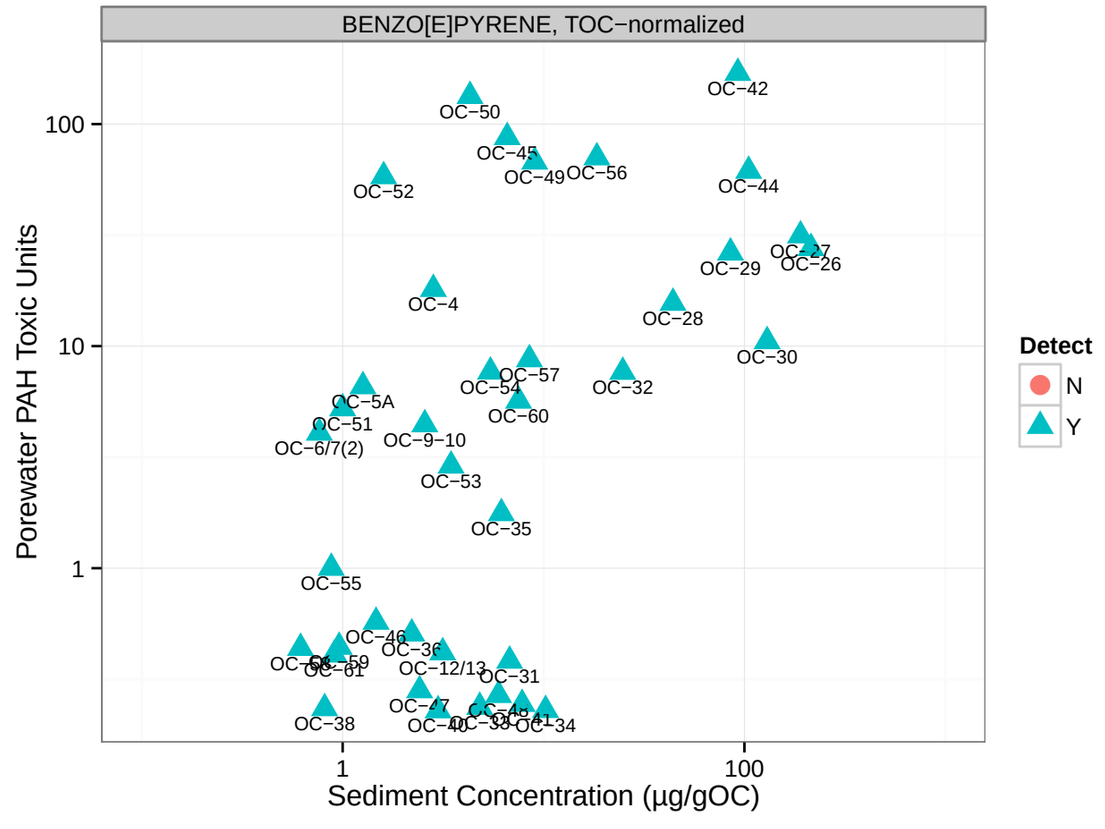

ACENAPHTHYLENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
0.1
10.0
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−56
OC−49
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−31
OC−47
OC−48
OC−33
OC−41
Detect
N
Y

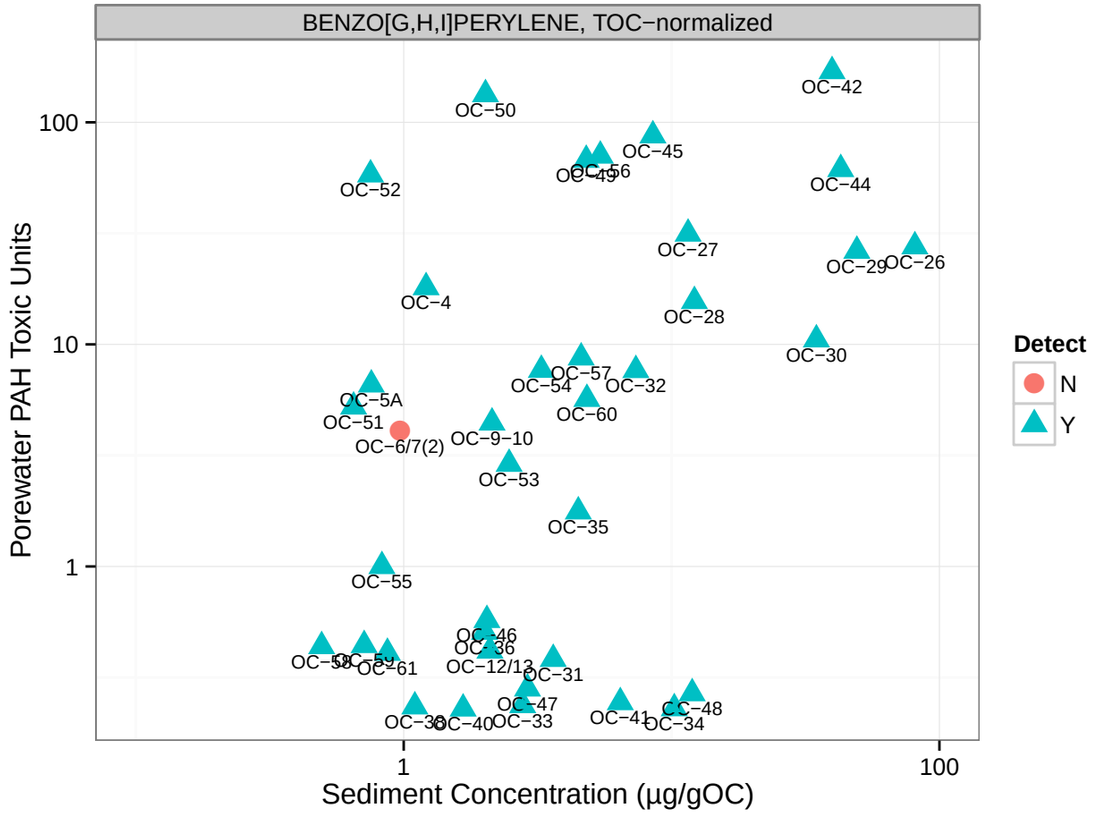

ANTHRACENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−58
OC−59
OC−36
OC−31
OC−38
OC−34
Detect
N
Y

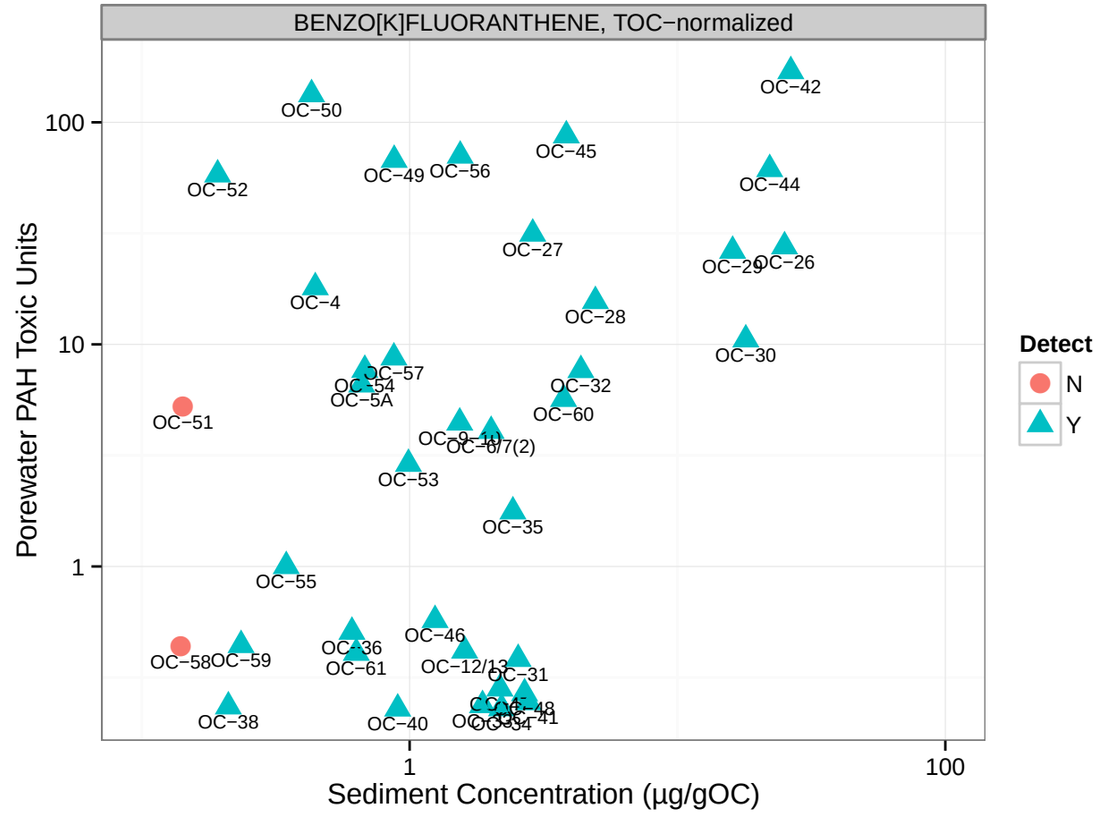

BENZO[A]ANTHRACENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

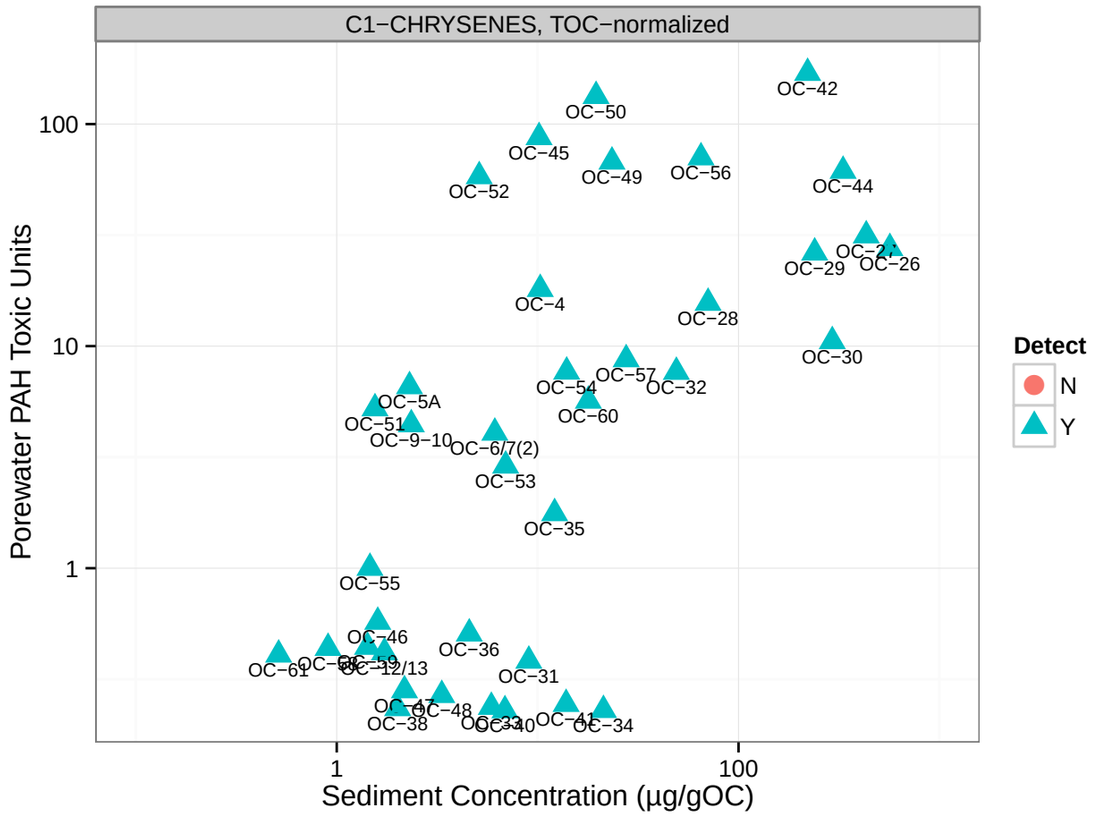

BENZO[A]PYRENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−51
OC−60
OC−6/7(2)
OC−9−10
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

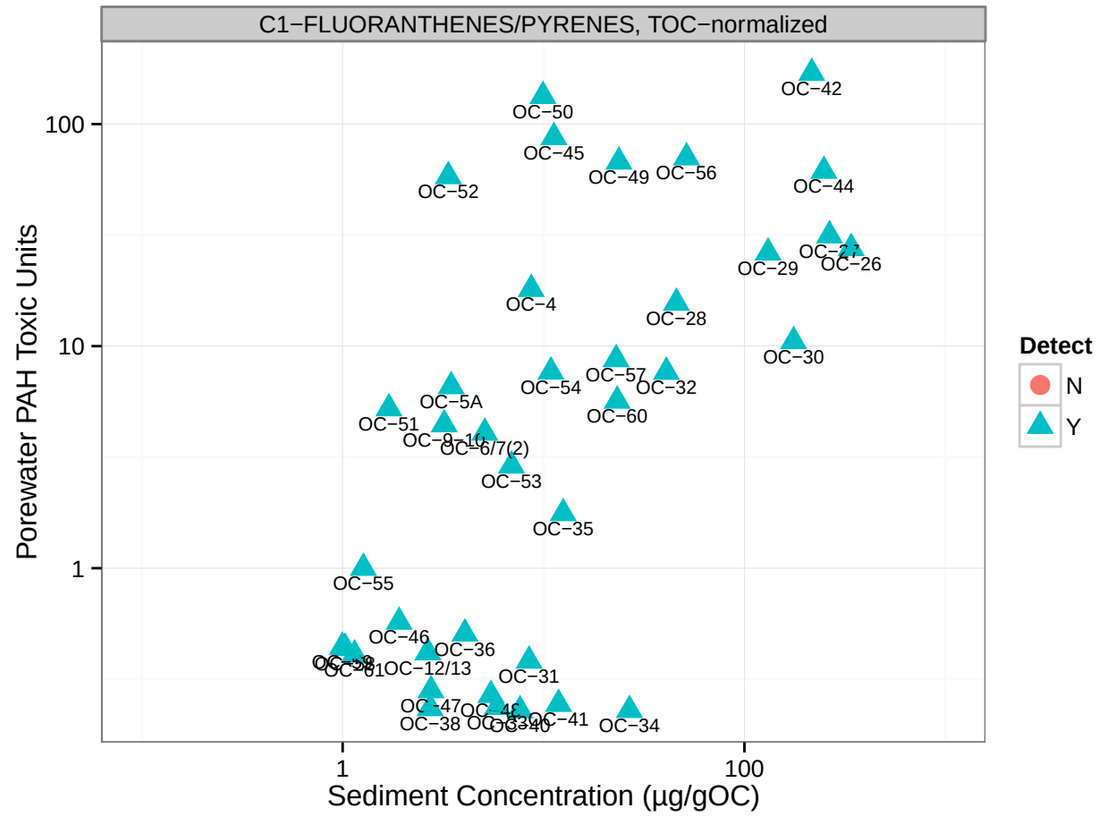

BENZO[B]FLUORANTHENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

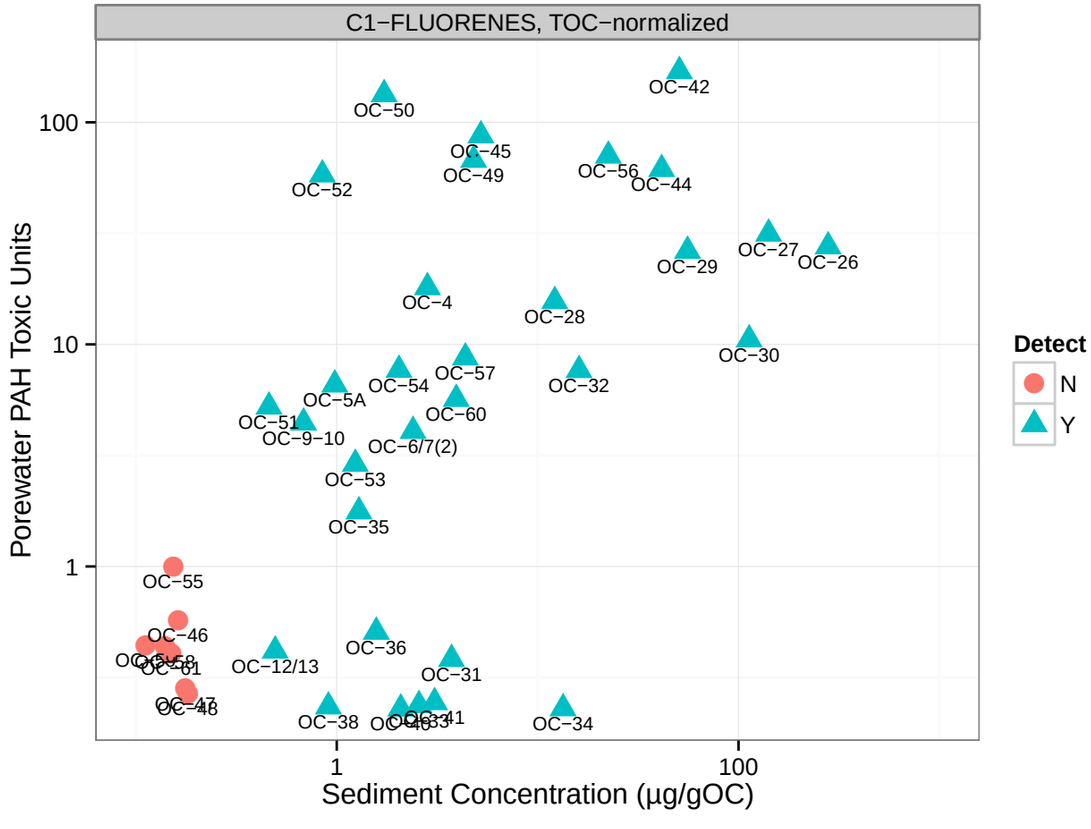

BENZO[E]PYRENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−34
Detect
N
Y

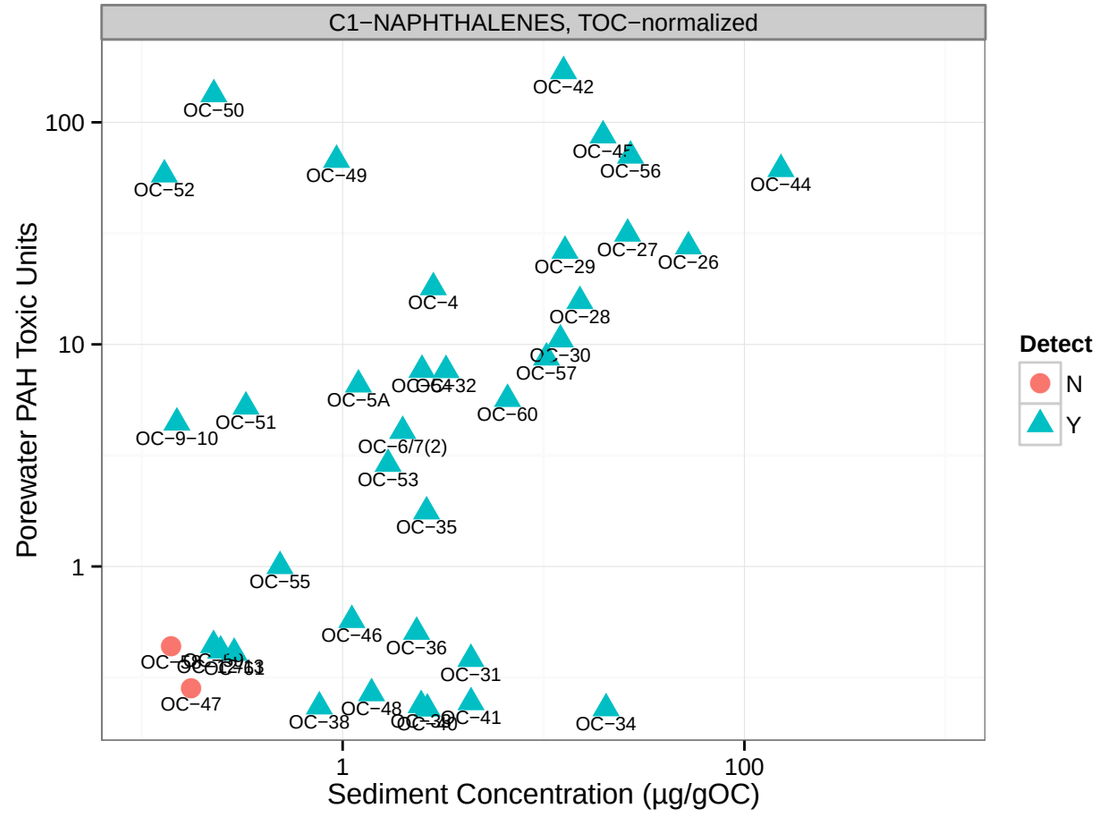

BENZO[G,H,I]PERYLENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−33
OC−41
OC−34
Detect
N
Y

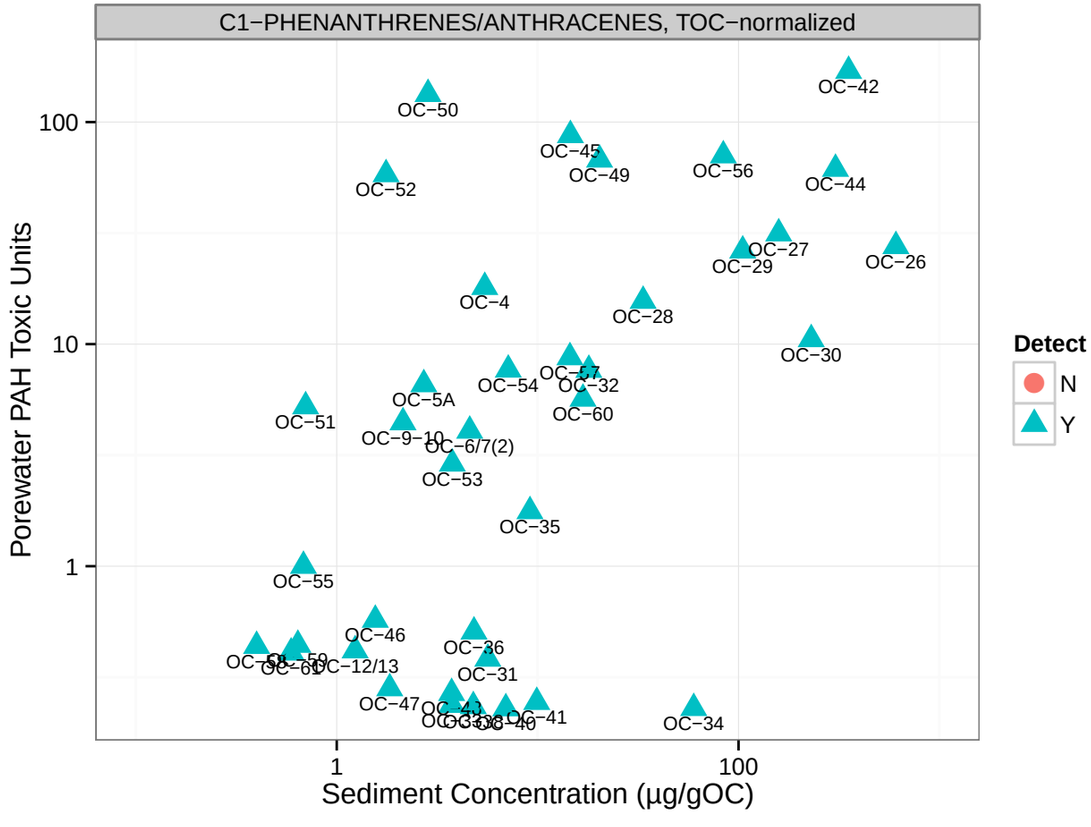

BENZO[K]FLUORANTHENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−59
OC−61
OC−12/13
OC−31
OC−38
OC−40
OC−41
OC−34
Detect
N
Y

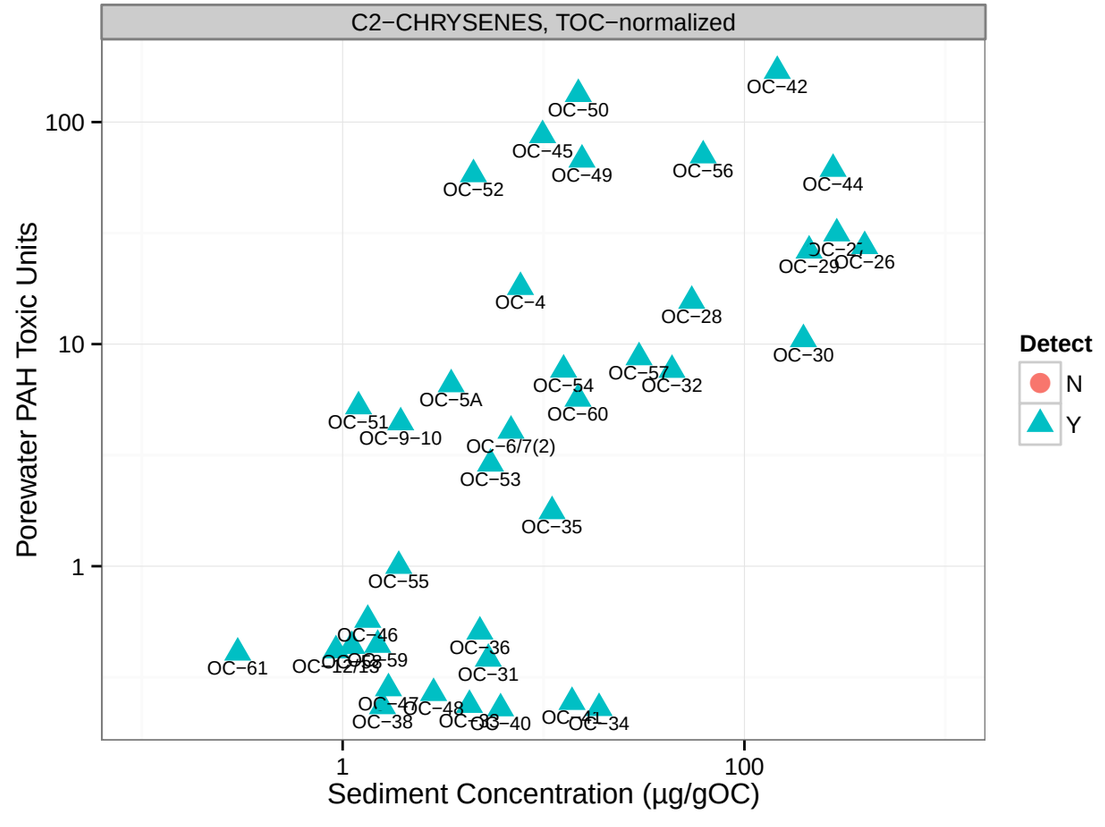

C1−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−12/13
OC−31
OC−47
OC−48
OC−38
OC−40
OC−41
OC−34
Detect
N
Y

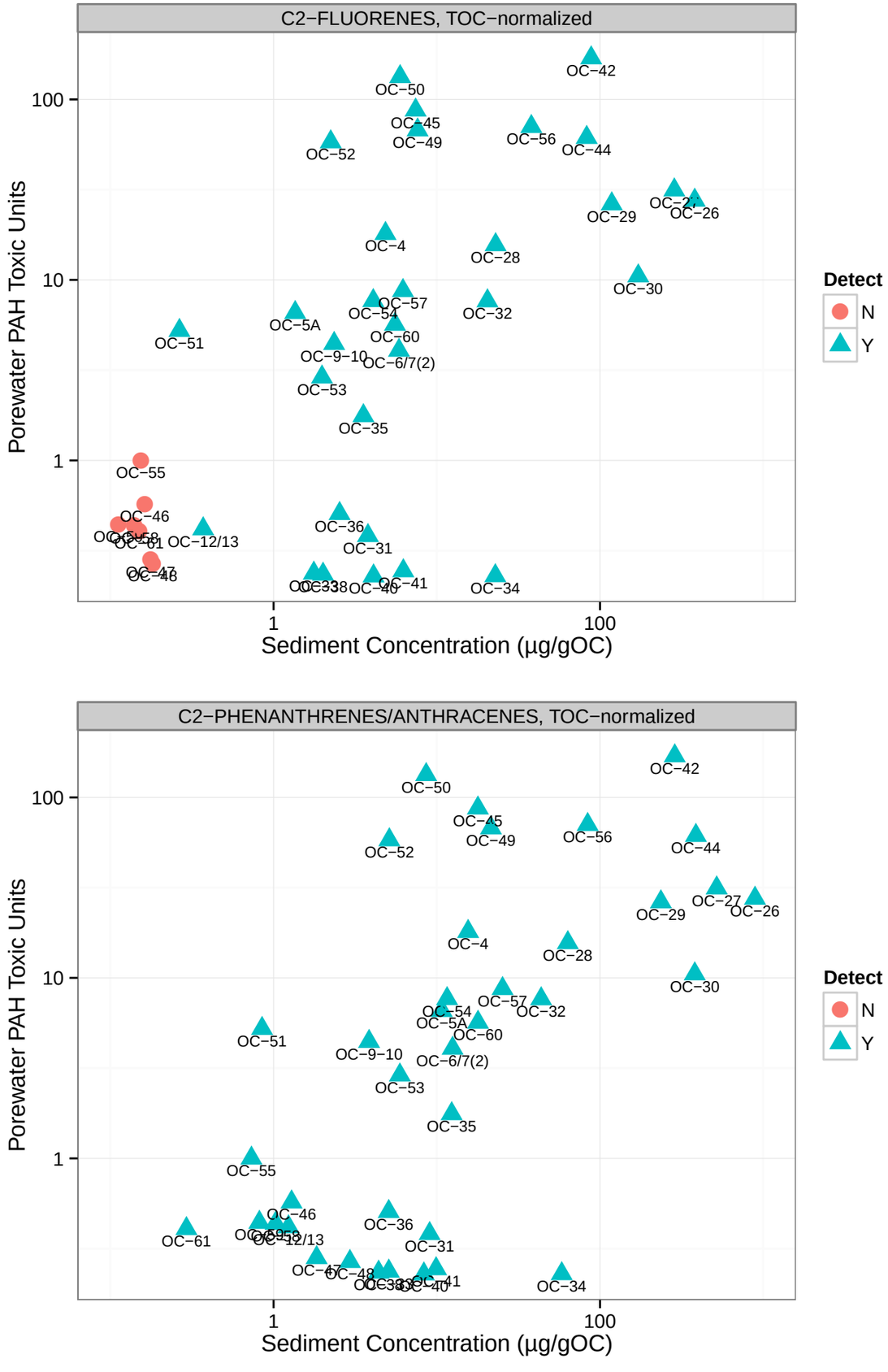

C1−FLUORANTHENES/PYRENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−61
OC−12/13
OC−31
OC−47
OC−38
OC−41
OC−34
Detect
N
Y

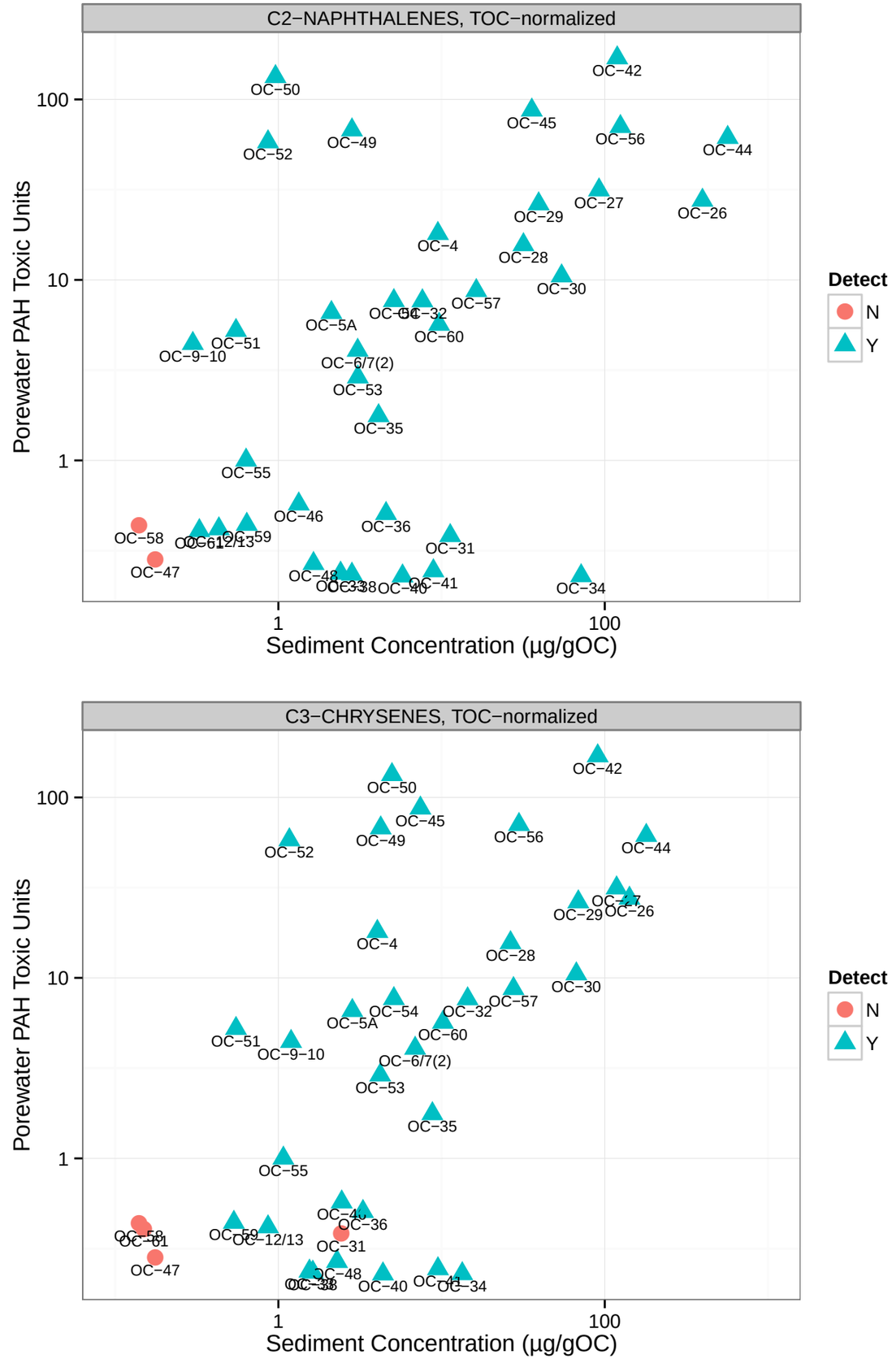

C1−FLUORENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−47
OC−38
OC−34
OC−41
Detect
N
Y


C1−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−52
OC−49
OC−56
OC−44
OC−29
OC−27
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
OC−60
OC−9−10
OC−51
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−31
OC−47
OC−38
OC−34
OC−41
Detect
N
Y


C1−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−12/13
OC−31
OC−47
OC−34
OC−41
Detect
N
Y

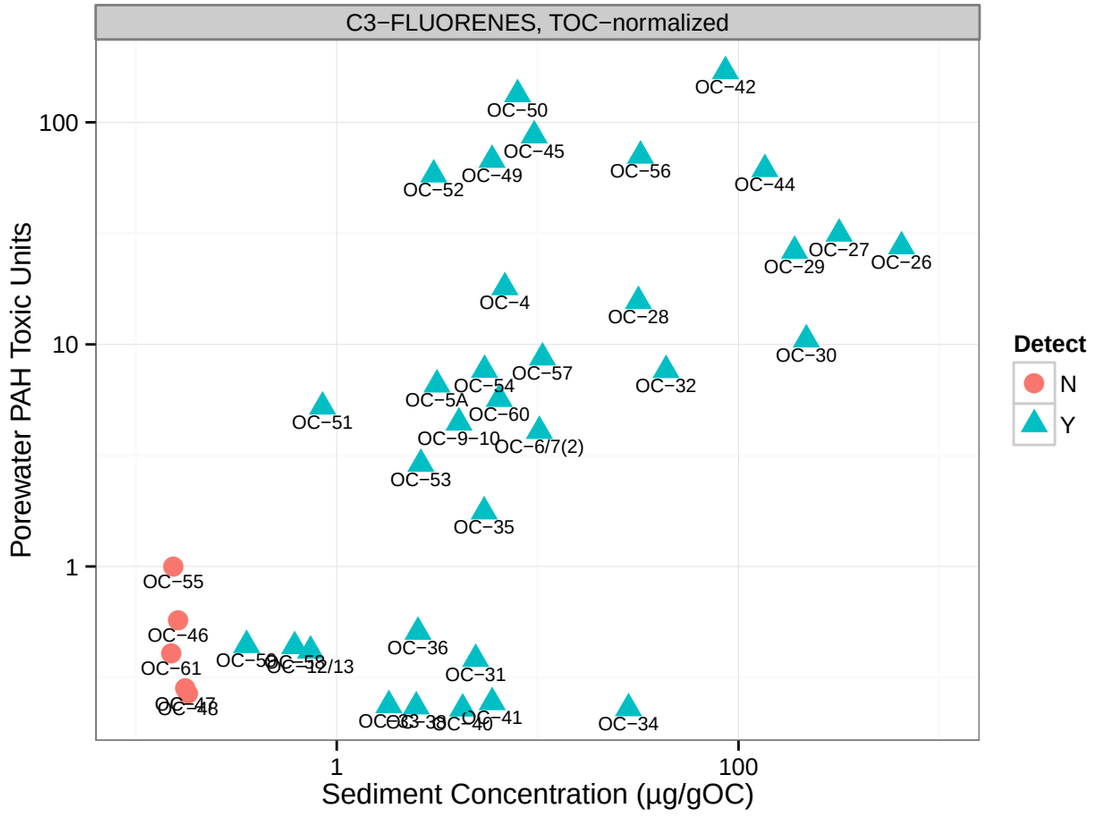

C2−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
1
100
Sediment Concentration (µg/gOC)
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
OC−54
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−61
OC−46
OC−36
OC−31
OC−47
OC−48
OC−38
OC−34
OC−41
Detect
N
Y

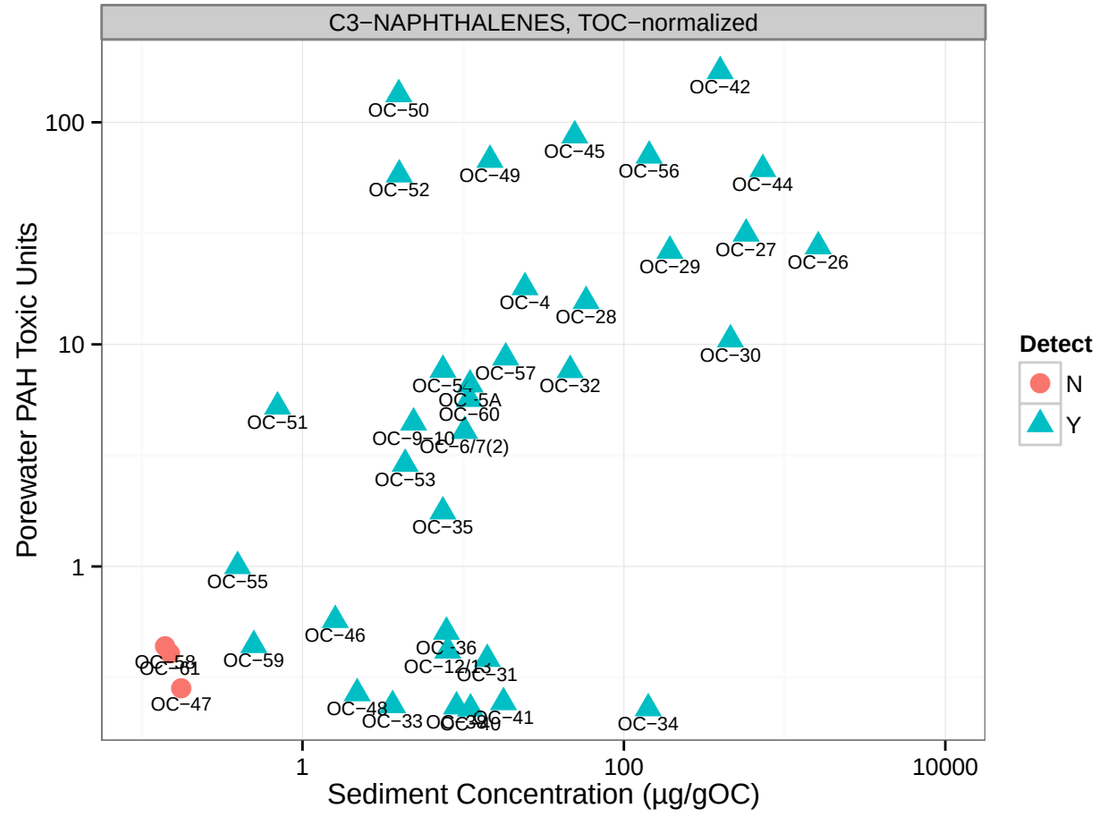

C2−FLUORENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

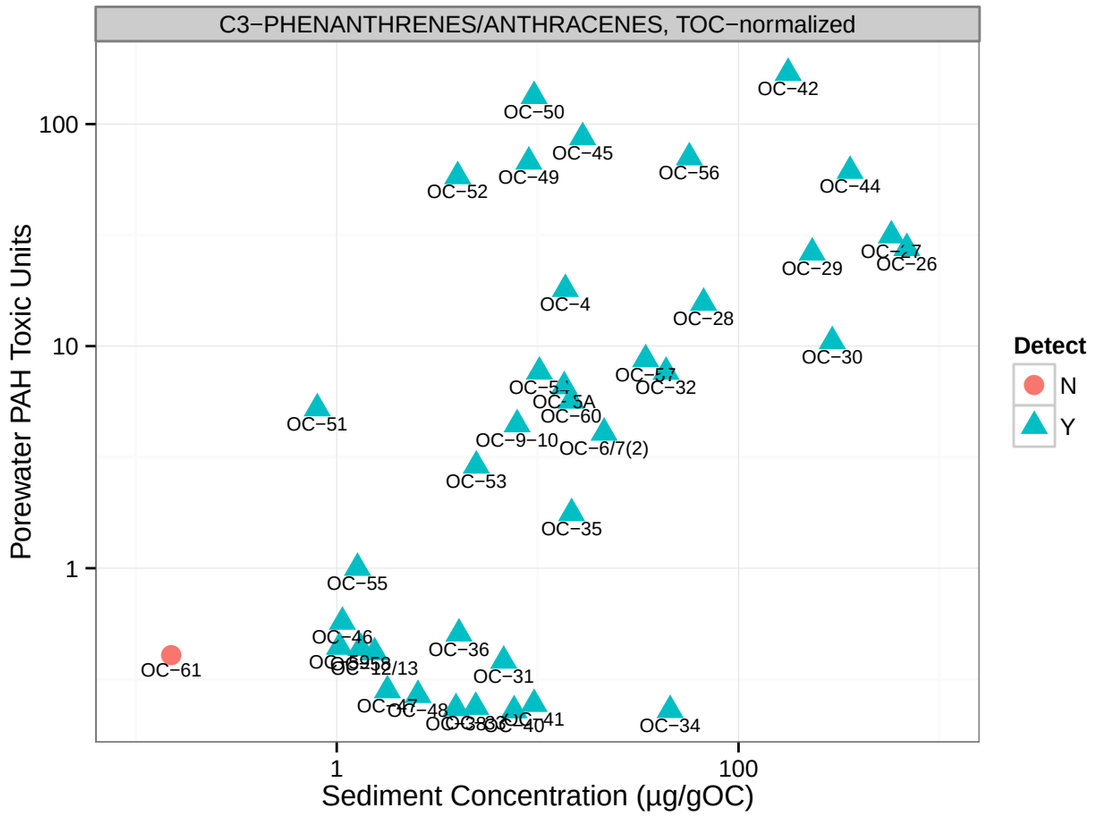

C2−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

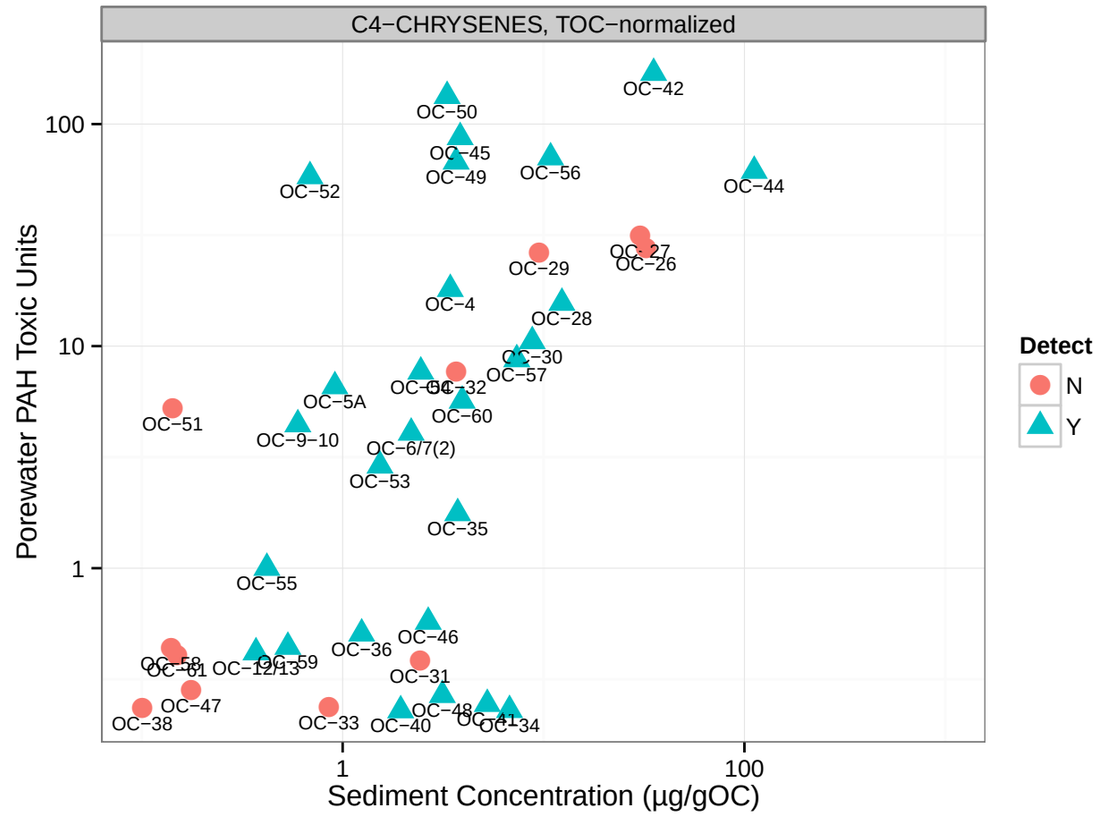
C2−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

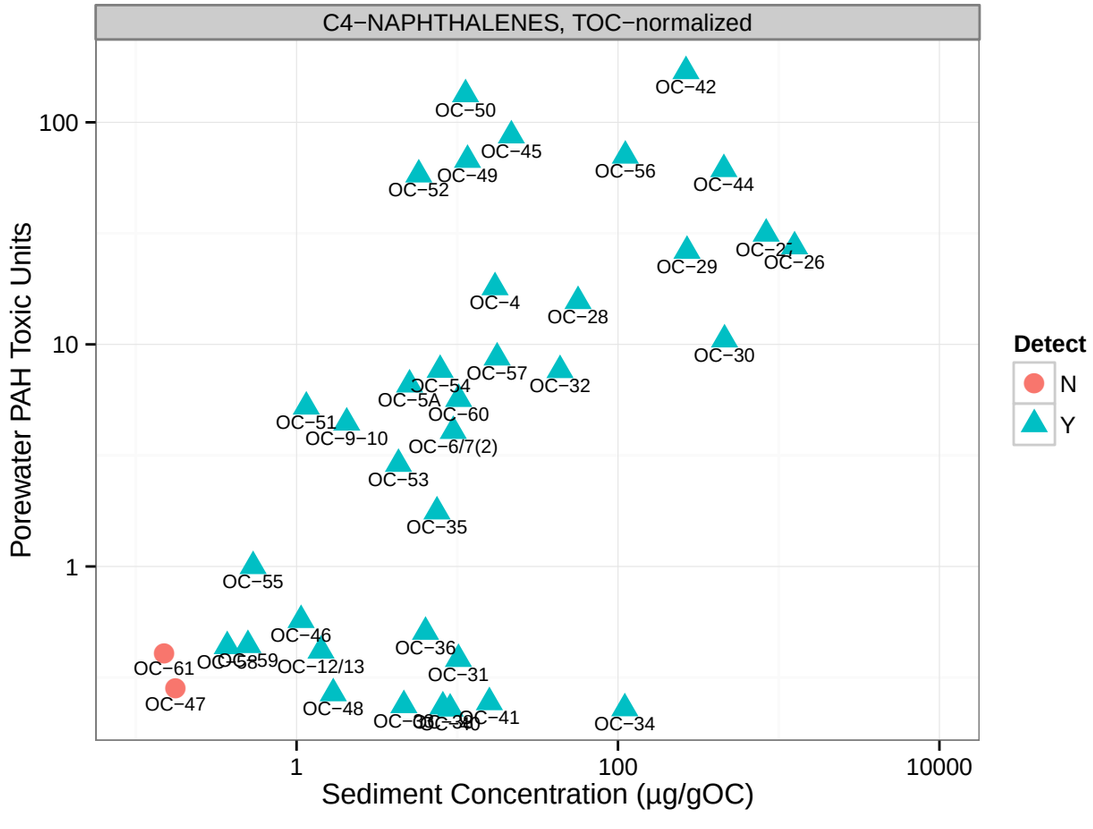
C3−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
Sediment Concentration (µg/gOC)
100
10
1
1
100
Detect
N
Y

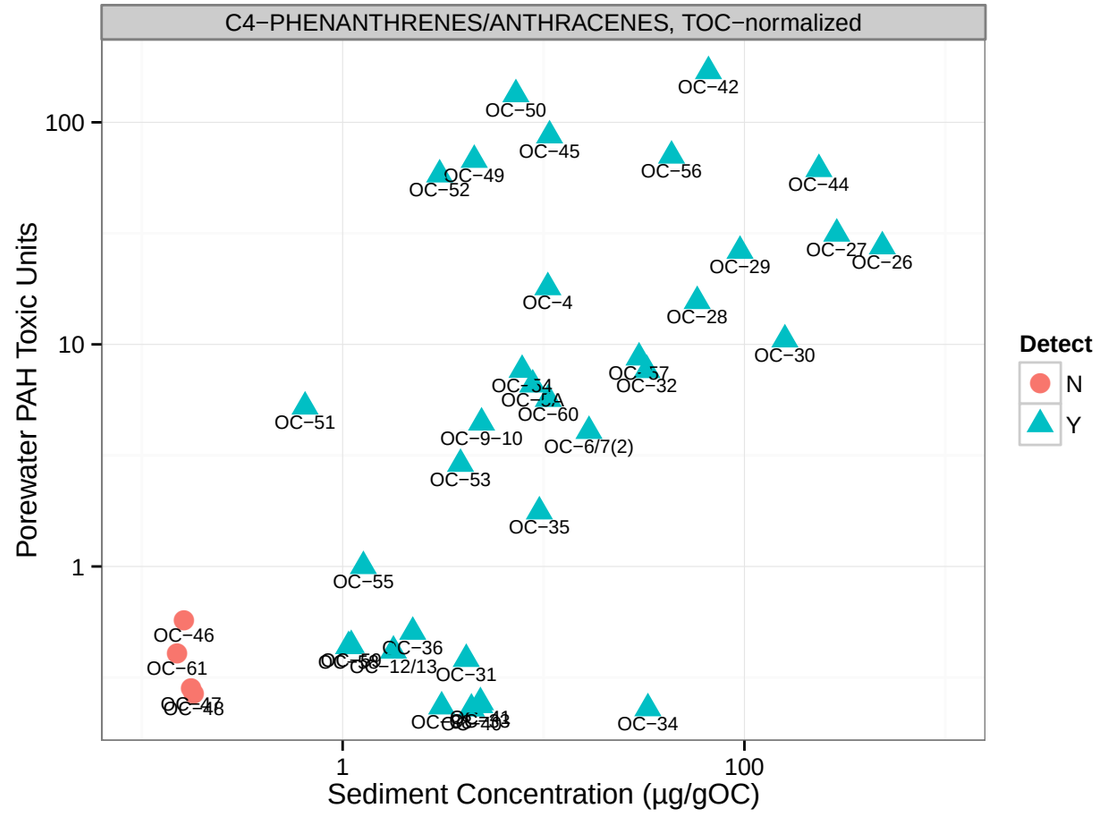

C3−FLUORENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−5A
OC−32
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−61
OC−59
OC−58
OC−12/13
OC−36
OC−31
OC−47
OC−48
OC−41
OC−34
Detect
N
Y

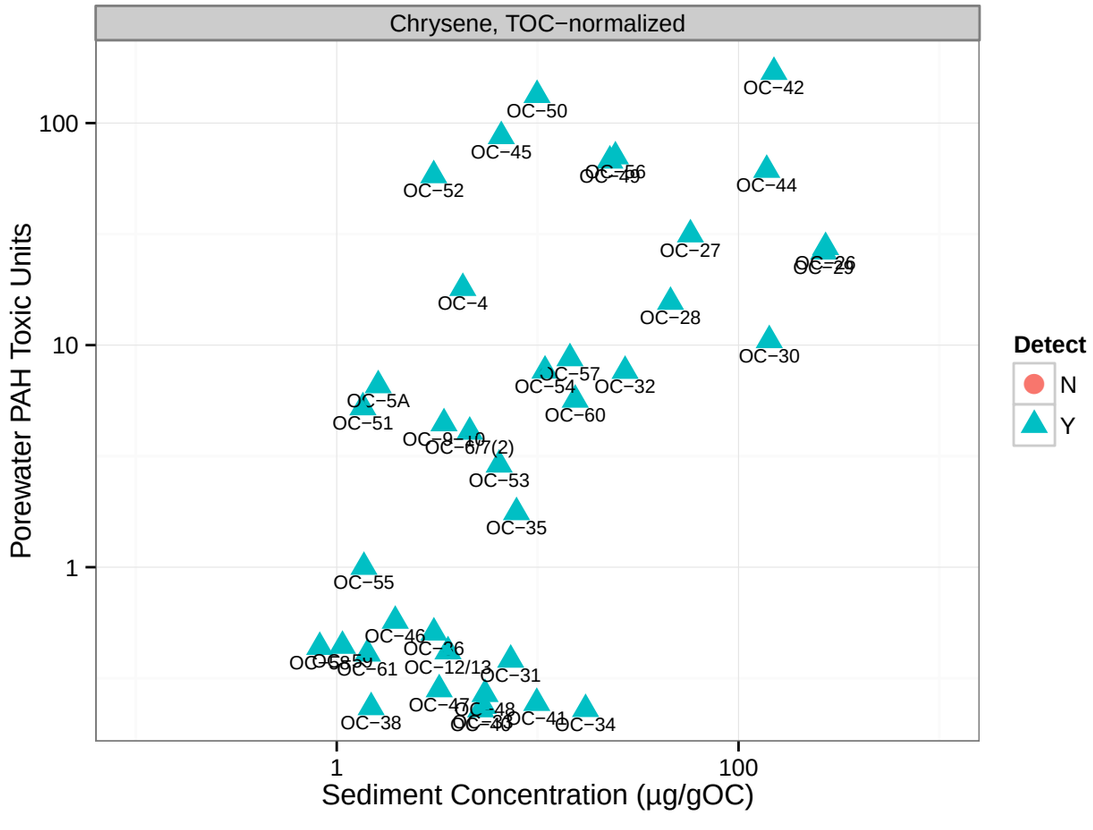

C3−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
10000
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−59
OC−58
OC−61
OC−12/13
OC−36
OC−31
OC−47
OC−48
OC−33
OC−41
OC−34
Detect
N
Y


C3−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−61
OC−36
OC−31
OC−47
OC−48
OC−41
OC−34
Detect
N
Y


C4−CHRYSENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−52
OC−56
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
OC−58
OC−61
OC−59
OC−12/13
OC−31
OC−47
OC−38
OC−33
OC−40
OC−48
OC−41
OC−34
Detect
N
Y


C4−NAPHTHALENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
10000
Detect
N
Y


C4−PHENANTHRENES/ANTHRACENES, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
Detect
N
Y


Chrysene, TOC−normalized
Porewater PAH Toxic Units
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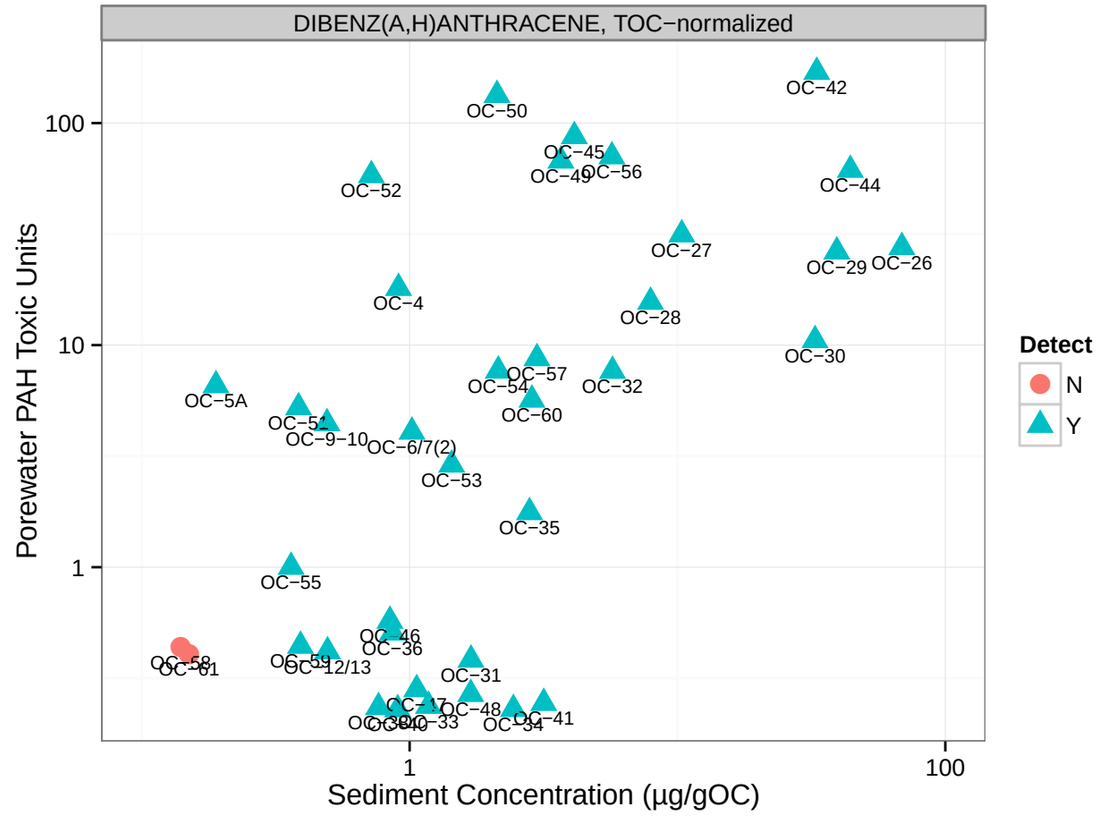
10
1
Sediment Concentration (µg/gOC)
1
100
Detect
N
Y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Porewater PAH Toxic Units
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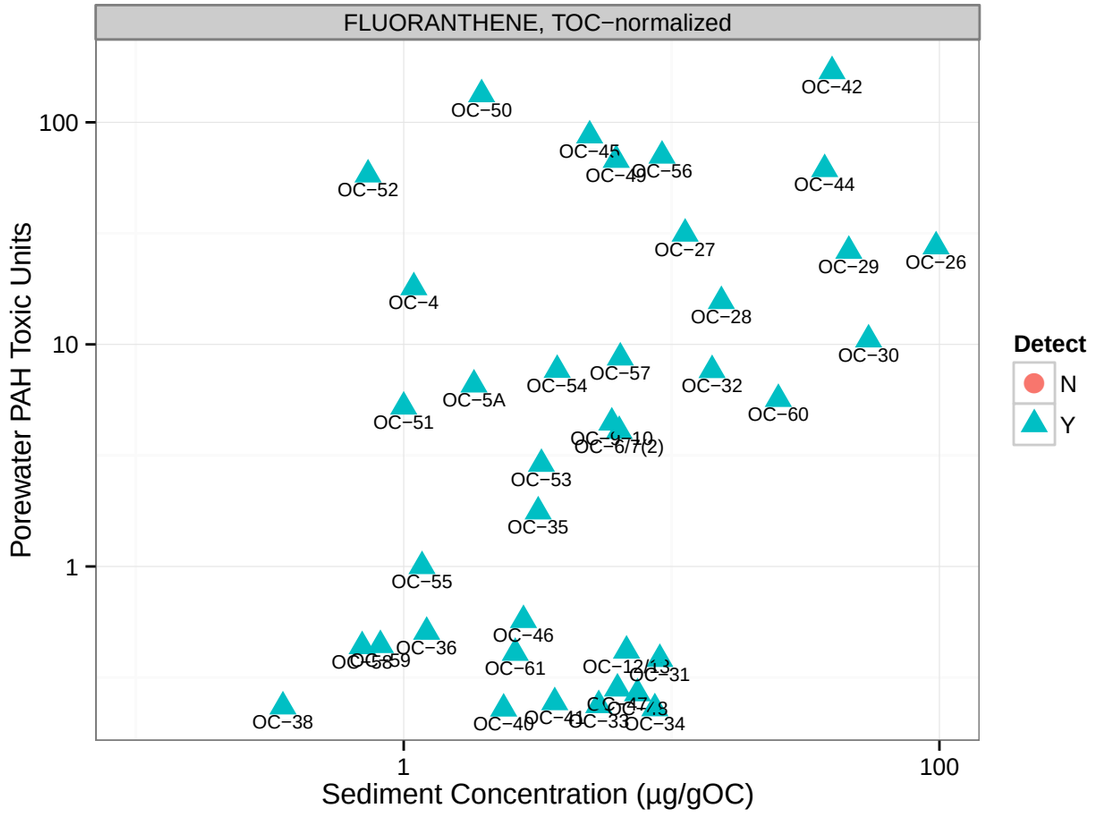
10
1
Sediment Concentration (µg/gOC)
1
100
Detect
N
Y


FLUORANTHENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−6/7(2)
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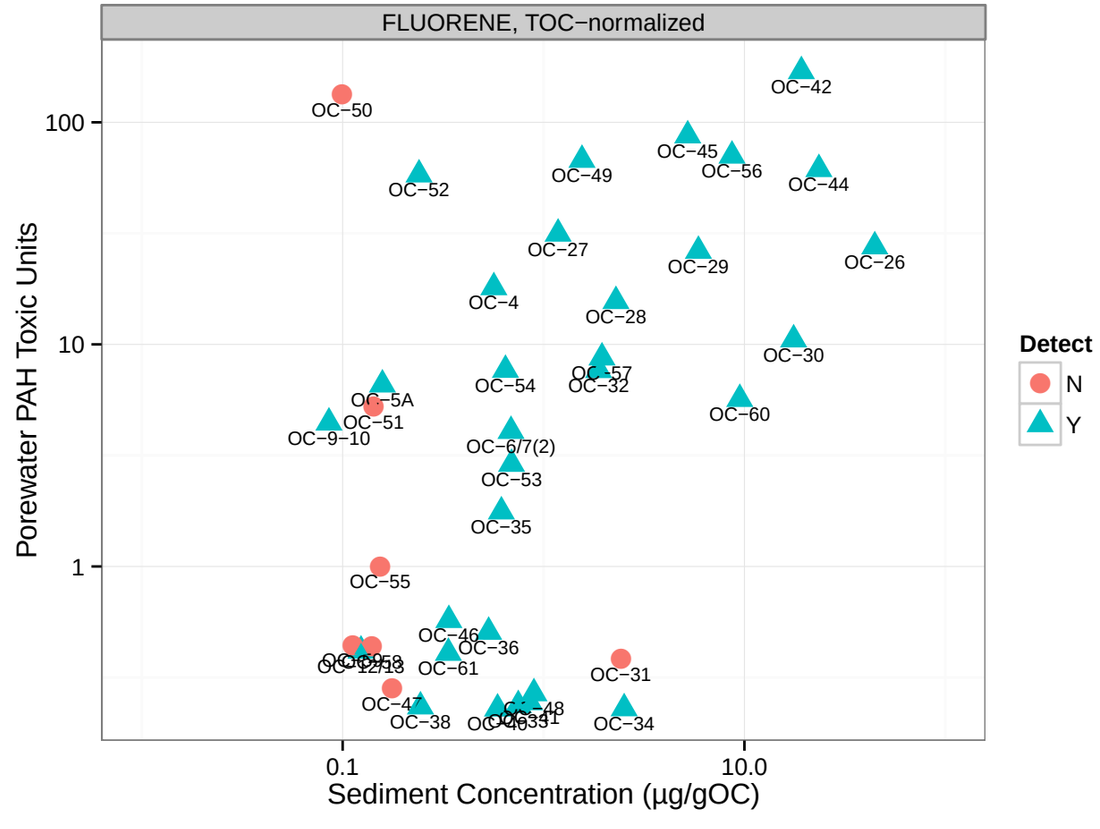
OC−36
OC−61
OC−31
OC−38
OC−40
OC−34
Detect
N
Y


FLUORENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
0.1
10.0
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
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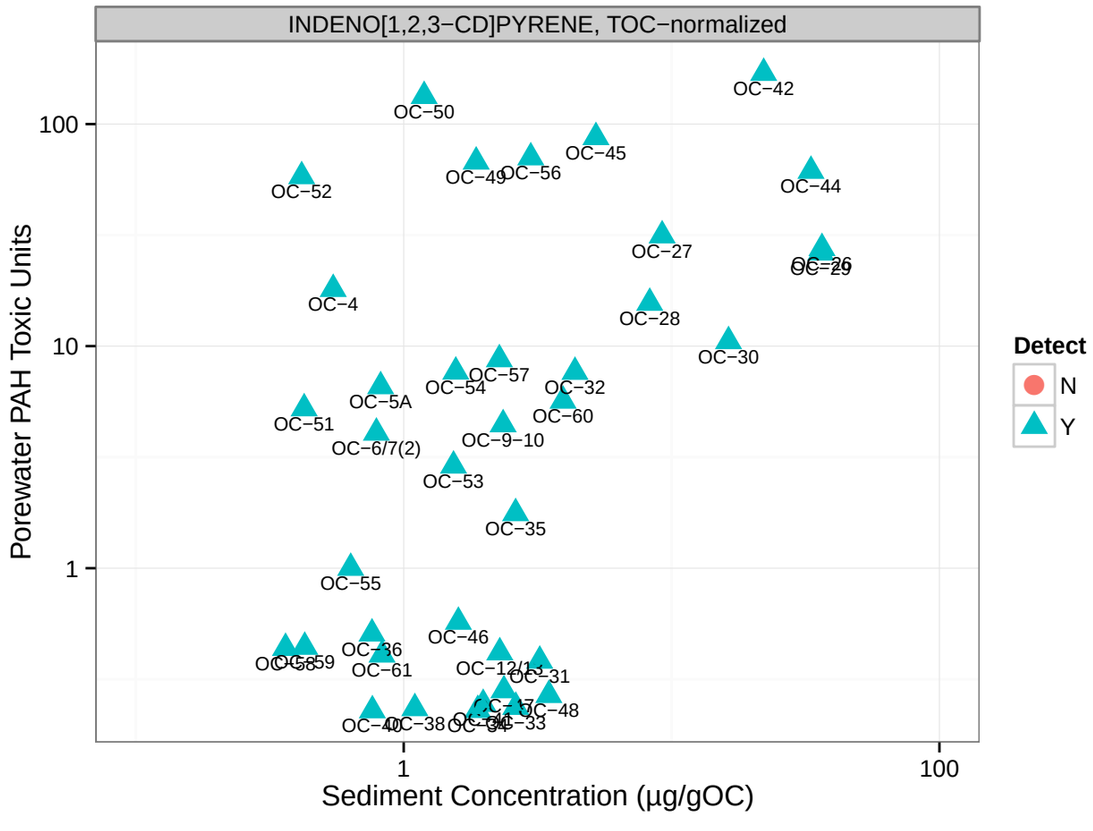
OC−31
OC−47
OC−38
OC−34
Detect
N
Y


INDENO[1,2,3−CD]PYRENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
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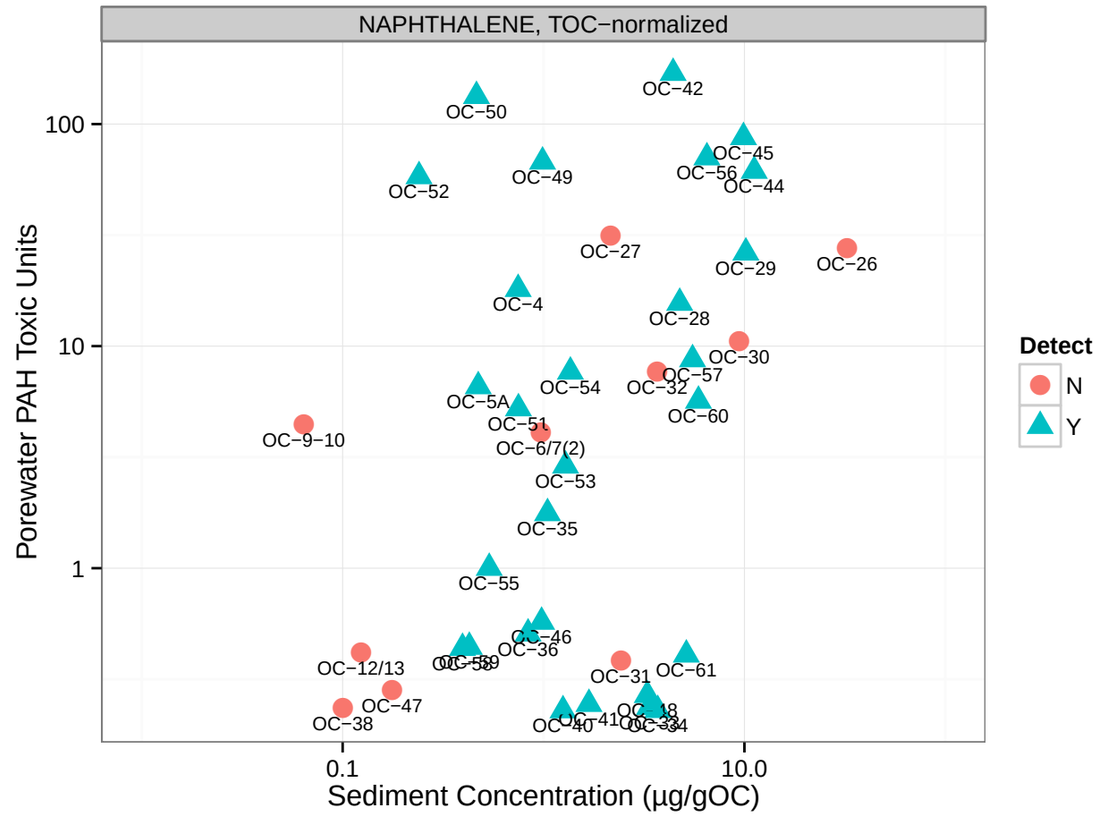
OC−36
OC−61
OC−31
OC−48
OC−38
OC−33
Detect
N
Y


NAPHTHALENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
0.1
10.0
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−54
OC−57
OC−32
OC−5A
OC−60
OC−51
OC−9−10
OC−6/7(2)
OC−53
OC−35
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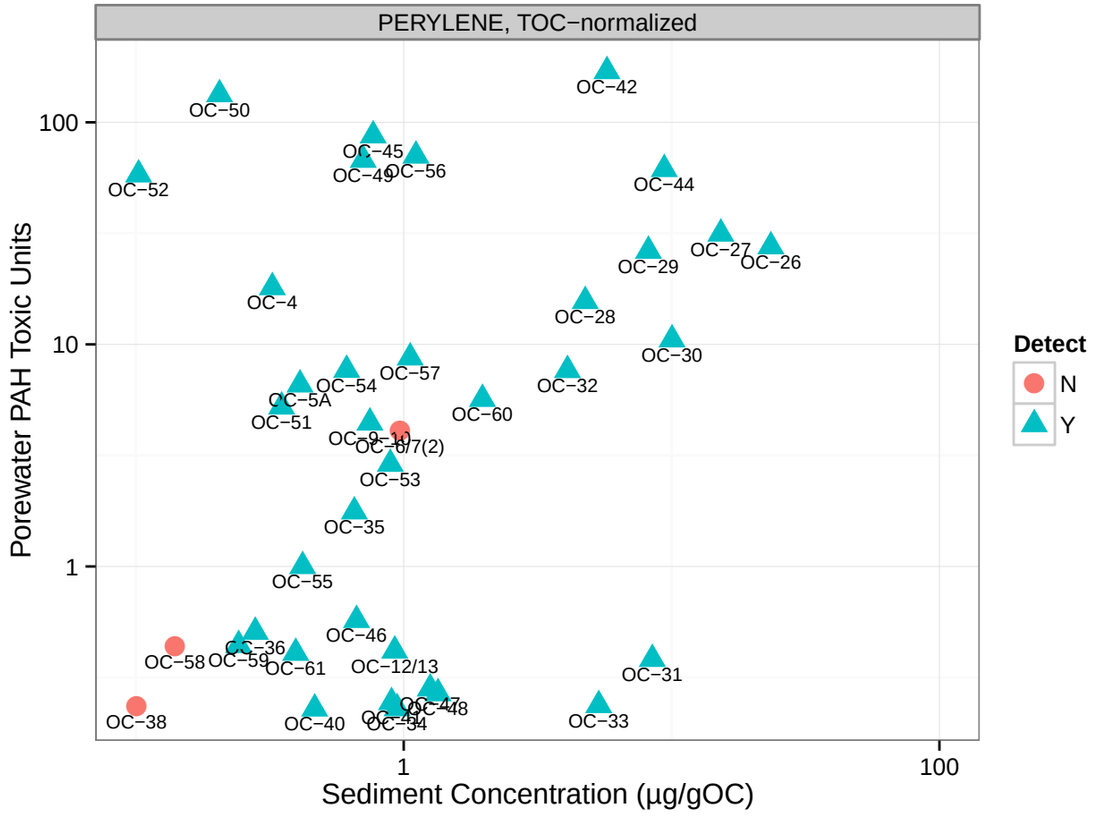
OC−47
OC−38
OC−41
OC−34
Detect
N
Y


PERYLENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−46
OC−36
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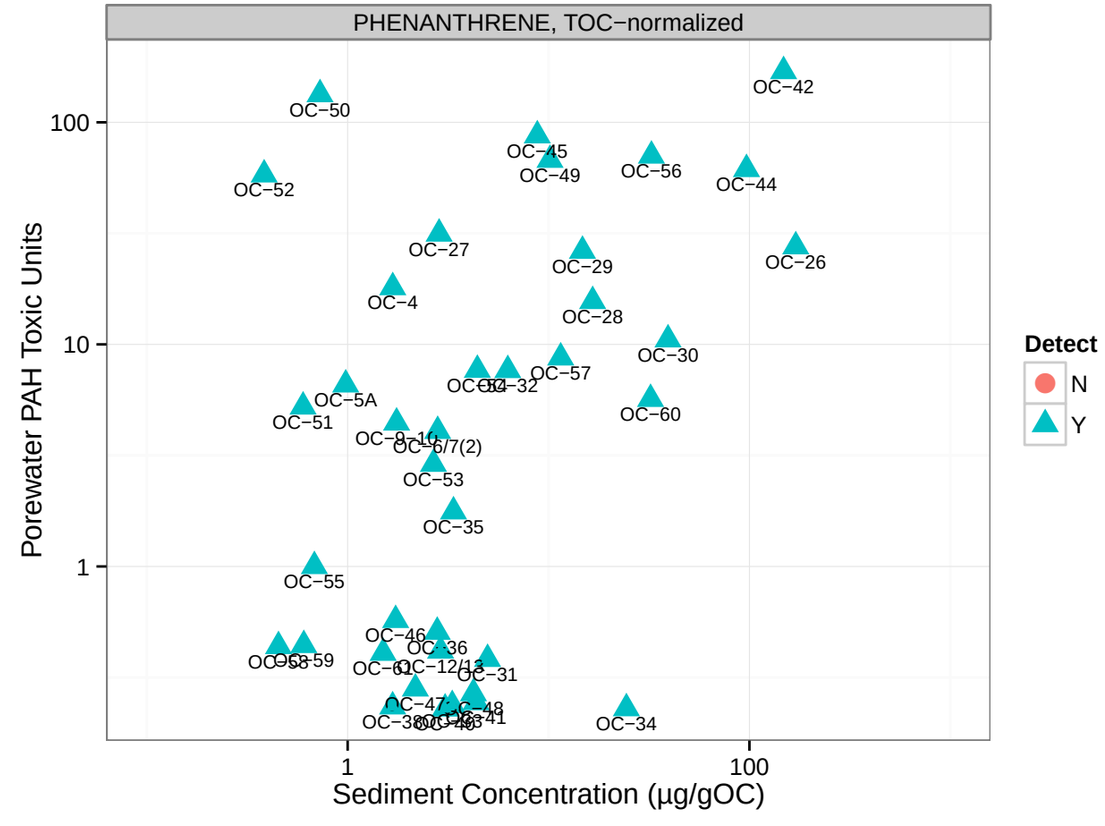
OC−31
OC−47
OC−48
OC−38
OC−40
OC−33
Detect
N
Y


PHENANTHRENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−44
OC−52
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−32
OC−5A
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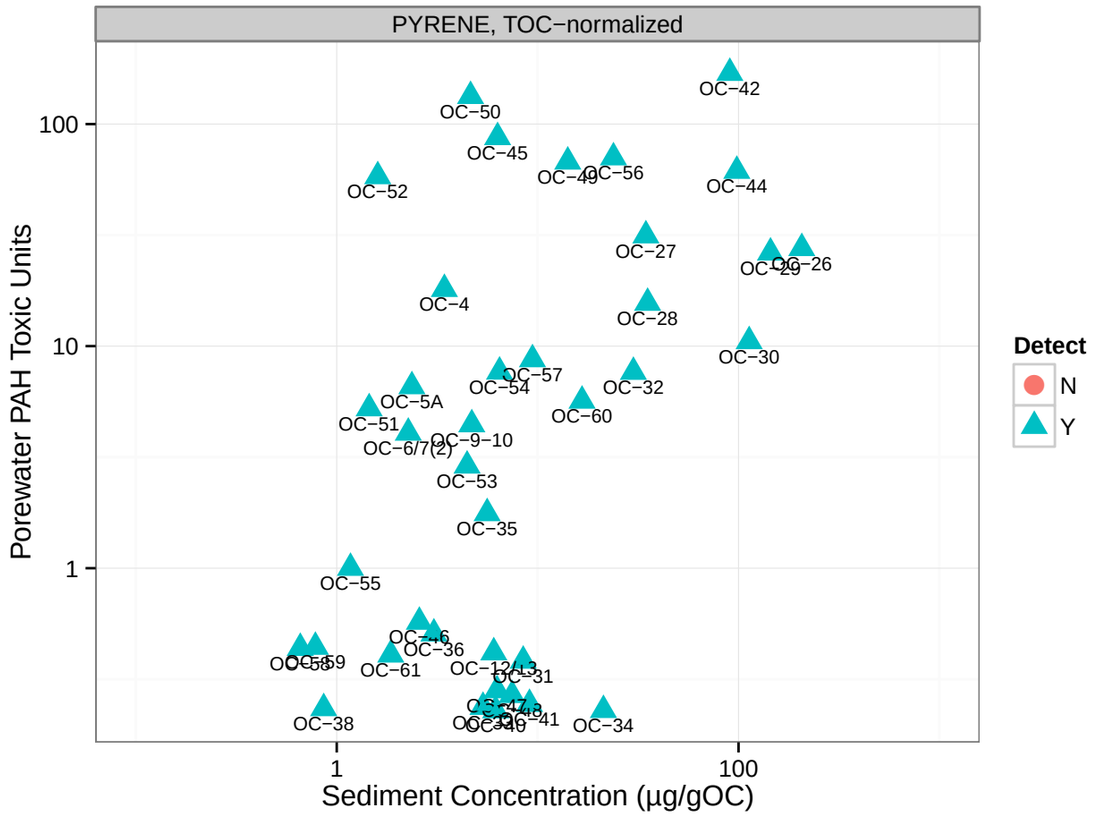
OC−35
OC−55
OC−46
OC−36
OC−31
OC−34
Detect
N
Y


PYRENE, TOC−normalized
Porewater PAH Toxic Units
100
10
1
Sediment Concentration (µg/gOC)
1
100
OC−42
OC−50
OC−45
OC−49
OC−56
OC−52
OC−44
OC−27
OC−29
OC−26
OC−4
OC−28
OC−30
OC−57
OC−54
OC−32
OC−5A
OC−51
OC−60
OC−9−10
OC−6/7(2)
OC−53
OC−35
OC−55
OC−36
OC−61
OC−12/13
OC−31
OC−38
OC−34
Detect
N
Y

Attachment 4

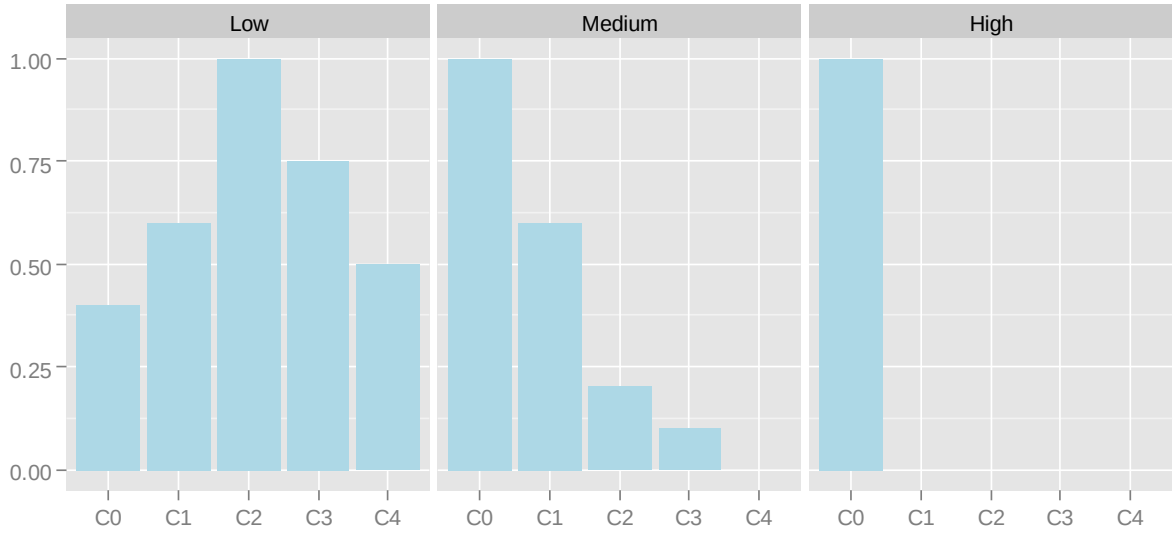
PAH Fingerprinting Analysis

1 PAH Fingerprinting

Polycyclic aromatic hydrocarbons (PAHs) are hydrocarbon compounds that are most commonly composed of two to six aromatic rings. Hundreds to thousands of PAHs have been found in nature, representing a diverse family of chemicals. PAHs are formed by a number of different processes, both natural and anthropogenic. Boehm (2006) describes a number of general pathways for the formation of PAHs such as

- Slow, long-term intermediate temperature (100-300°C) formation of fossil fuels
- Rapid, high temperature (>500°C) incomplete combustion, or pyrolysis, of organic material
- Biosynthesis of individual PAHs by plants and animals

The formation of individual PAHs and the relative abundance of the PAHs formed through these pathways is dependent on the specific conditions of formation. Specifically, the PAH mixture is dependent on (1) the starting material, (2) the temperature, and (3) the duration. For example, the degree of alkylation, the addition of alkyl side chains, has been demonstrated to be largely a function temperature. PAHs with no alkyl side chains are classified as C0 parent compounds, one alkyl chain PAHs are C1, two alkyl or one ethyl chain PAHs are C2, and so on. Note that the C0 prefix for non-alkylated parent PAHs is often implied and not used when naming PAH isomers. Blumber (1976) shows that the degree of alkylation is inversely proportional to the temperature of formation as shown below:



Low temperature sources (100-300°C) are defined as petrogenic and include petroleum and coal. Medium (500-700°C) and high (~2000°C) temperature sources are defined as pyrogenic and are formed during the combustion of petroleum and organic matter. The specific PAH assemblage will vary according to the conditions of formation and therefore can be used to

differentiate, or fingerprint, sources. For the Duck and Otter Creek project, the goals of PAH fingerprinting are two-fold: (1) differentiate the PAH spectra in the sediments to ascertain the areas impacted by different sources and (2) use the PAH spectra to determine the source type(s) (e.g. petrogenic, pyrogenic). The analysis is based on ratios and multivariate analyses that are well documented and commonly employed in the literature.

1.1 Methods

Principal Components Analysis (PCA) and Hierarchal Cluster Analyis (HCA) are multivariate methods used to simplify the variability in a large number of variables to a form that is more easily explored and interpreted (Wenning et al 1993, Venebles and Ripley 2002, USEPA 2004, Johnson et al 2007). Other commonly employed techniques include the use of double ratio plots and isomer profile plots. Ratios of certain PAHs can also be used to identify and differentiate sources of petrogenic and pyrogenic hydrocarbons (Sauer and Uhler 1994, Douglas et al. 1996, USEPA 2004).

1.1.1 PCA and HCA

PCA is commonly used to identify and differentiate chemical sources (e.g., Sauer and Uhler 1994; Johnson et al 2007). PCA is a mathematical procedure that transforms a number of potentially correlated variables into a smaller number of uncorrelated variables called principal axes (or eigenvectors). These principal axes are standardized linear combinations of, for example, individual chemical compositions expressed as a proportion of the total that account, in descending order, for as much of the variability as possible. Simple graphical presentation of these principal axes demonstrates the compositional relationships between samples; samples with similar compositions fall into distinct groupings. The advantage of PCA is that a sample with 10 or more reported compounds can be projected onto a simple X-Y plot of the first two principal axes that retains much of the information of the original data. This type of plot is called a principal component or score plot.

Another strength of PCA is that relationships between variables and samples can be evaluated. A plot of the contribution of the original variables to defining the new coordinate system, as calculated during the analysis (i.e., first two principal axes), is called a loading plot. Like the principal components plot, variables that plot near each other may be correlated in the original samples. In addition, the location of variables in the loading plot reflects their effect on the placement of samples on the principal components plot. For example, a sample with a positive loading in the first two principal axes is most likely enriched in variables that have a positive loading in the first two principal axes in the loading plot. PCA allows for the evaluation of all of the variables together and provides information in a simple way to identify samples with similar chemical fingerprints and to identify which chemicals are most diagnostic of a particular source or environmental sample.

Tree based cluster analysis is a data visualization technique that identifies groups of samples that share similar PAH profiles. Samples are successively linked together in a dendrogram (hierarchal tree diagram) based on increasing dissimilarity (or distance). Samples sharing the most similar profiles are joined together, and clusters form between more similar sets of samples. Similarity is measured by the distance between points.

In this application, the sample matrix is defined by the number of different PAH compounds and the total number of samples. There are several mathematical procedures that can be used to define distances between samples and create clusters. These methods include Ward's distance method, single linkage, complete linkage, average, median, or centroid. With the exception of Ward's method, all of these methods are based on the differences in distance between the sample matrices. The Ward's method uses an analysis of variance approach to evaluate the distances between clusters. This method attempts to minimize the sum of squares of any two (hypothetical) clusters that can be formed at each step. This method is regarded as the most efficient and produces compact clusters of similar size. The Ward's method used here is the preferred method and demonstrates concordance with the other methods.

Hierarchal tree clustering analysis is not a typical statistical test. There is no *a priori* hypothesis that is tested by the procedure; it is rather a powerful visualization of the dissimilarity between samples. It is another line of evidence to confirm or refute suspected relationships between environmental samples and hydrocarbon sources. It is a useful data visualization technique that groups samples with common sources into visually distinct clusters. Samples that represent mixtures of one or more sources should be related to these sources, but should be located at a greater distance depending on their relative contribution of each source. The advantage of this procedure is that it considers all of the degrees of freedom (i.e., the complete set of variables) in the analysis. It also provides a simple to understand visualization of a relatively complicated analysis.

PCA and HCA can be combined into a single data visualization. As described above, in a PCA plot, the plot symbols or colors can be used to express additional information. The plot symbols or colors in the PCA plot can be used to show cluster membership from the HCA. If samples of the same cluster plot close to each other in PCA space, the two techniques exhibit concordance and therefore provide supporting lines of evidence.

1.1.2 Double Ratio Plots

The ratios of certain PAHs can be used to identify and differentiate sources of petrogenic and pyrogenic hydrocarbons (Sauer and Uhler 1994, Douglas et al. 1996). The FL/FL+PY (fluoranthene/fluoranthene + pyrene) ratio is often used to distinguish low temperature petrogenic sources from medium and high temperature pyrogenic sources. Petrogenic sources generally exhibit a ratio less than 0.40. A ratio between 0.40 and 0.50 indicates petroleum combustion, and values greater than 0.5 indicates wood or coal combustion. Indeno(c,d)pyrene and benzo(ghi)pyrene (ID/ID+BgP) have also been used to identify petrogenic and pyrogenic sources (Bobak 2010).

1.1.3 PAH Composition Profile

The ratios of the various PAHs to each other can also be explored based on the complete PAH composition profile. The PAH composition profile presents the proportion of the total for each isomer, arranged from lightest to heaviest, for individual samples or groups of samples. The profile is particularly useful in exploring the relationship between the alkylated homologues and parent PAHs as it related to petrogenic versus pyrogenic sources. Additionally, the relative abundance of lighter versus heavier isomers can also be used to differentiate sources. For example diesel fuel is enriched in the lighter isomers, crude is less enriched, and coal tar is

enriched in the heavier isomers. Additionally, weathering can result in the loss of lighter isomers and therefore alter the PAH isomer profile.

1.2 Results and Discussion

Sediment samples collected in 2007, 2010, and 2011 and analyzed for alkylated PAHs were used in the PAH source analysis. Before statistical analysis could begin, the data summarized to determine the frequency of detection for each PAH isomer that was analyzed in both data sets. PAHs that were not quantified in all samples were excluded. When analytes with a low frequency of detection are included in the source analysis there is a significant danger of biases. Specifically, given that the data were collected during multiple sampling programs and analyzed by multiple laboratories, the relative composition of infrequently detected PAHs can be a function of the detection limit and the total PAH concentration in the sample rather than real differences in composition (Johnson et al., 2006). These factors are not relevant to source analysis, and the inclusion of these analytes can result in erroneous conclusions such as samples being classified as similar based on the sampling event and analytical methods rather than the true PAH composition.

For this analysis, PAHs with a frequency of detection greater than 70% in both GLNPO 2007 and GLLA 2010-2011 sampling events were included. The frequency of detection for C1-naphthalane was 0.5 and 0.95 in the GLNPO and GLLA datasets. Given that naphthalene can be an important indicator isomer, and the relationship between the naphthalene homologue groups can useful in source diagnostics, a parallel analysis was conducted on a dataset in which this isomer was included. The frequency of detection for C0-naphthalane was 0.3 and 0.7 in the GLNPO and GLLA dataset, a value too low to permit inclusion in the analysis. The list of PAHs included in the analysis is: C1-naphthalenes, C2-naphthalenes, C3-naphthalenes, C4-naphthalenes, Fluorene, C2-fluorenes, C3-fluorenes, Anthracene, Phenanthrene, C1-Phenanthrenes/Anthracenes, C2-Phenanthrenes/Anthracenes, Fluoranthene, Pyrene, C1-fluoranthenes/pyrenes, Benzo[a]anthracene, Chrysene, C1-Chrysenes, C2-chrysenes, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Benzo[e]pyrene, Benzo[a]pyrene, Perylene, Indeno[1,2,3-cd]pyrene, Dibenz(a,h)anthracene, and Benzo[g,h,i]perylene.

1.2.1 PCA and HCA

PCA and HCA were used to examine the PAH spectra associated with sediment samples collected from Duck Creek, Otter Creek, and local urban comparison streams. Prior to analysis, the data row normalized so concentrations were express as a proportion of total. The PCA analysis utilized data that standardized to a centered mean of zero and a standard deviation of one (Johnson et al. 2007) for each analyte. For the HCA analysis the data was range transformed by analyte (Johnson 2007 et al., Meich 1976) resulting in a minimum of zero and a maximum of one and approximately homogenous variances. For all of these analyses, the expanded dataset was used, which includes C1- naphthalenes in addition to the isomers with a frequency of detection of > 0.7 in both data sets. However, when C1- naphthalenes were excluded from the data set the results were virtually identical and the conclusions discussed below remain as unchanged.

The results of the PCA analysis are presented in Figure 1. The top panel shows the proportion of the variance accounted for by each principal component. The lower panel shows the scores

for each sample and the loadings associated with each PAH isomer for the first two principal components. The results show that bulk of the variability is accounted for in the first two principal components. The bottom panel shows the loadings and scores plots from the analysis, with the plot symbols shaded to denote the data source. The results also show that there is considerable overlap between the two sample programs (GLNPO 2007 and GLLA 2010/2011).

The analysis was extended in Figure 2 to consider location and comparisons to a source library (Boehm 2006, Wang et al. 2003, unpublished data).The plot symbols are colored to denote the areas of sample collection and source type. In this plot, samples that are located close to each other have similar PAH compositions. The plot of the first two principal components shows that the two creeks intermingle in the PCA plot, suggesting similar sources of PAHs to both areas. The results also roughly plot in a triangular region, suggesting three or more end members or sources (Johnson et al 2007). Although not shown, a plot of the second and third principal components does not provide additional insight but rather serves to confirm observations from the first two principal components. A comparison to the source profiles shows that the samples in the lower left, which included background, are consistent with urban background sediment and have a high degree of similarity with coal tar/pitch. Samples in the upper right are most consistent with fuel oils, specifically diesel fuels.

The results of the HCA analysis are shown in Figure 3 in the form of a dendrogram. In this analysis, samples are iteratively grouped together based on the degree of similarity, with samples joined by horizontal lines at the bottom of the plot being more similar than groups of samples joined by horizontal lines higher up in the plot. Based on professional interpretation of the branches of the dendrogram, the data set was assigned to four major clusters, denoted by the colors of the branches and the sample ID labels. The results confirm the observation from the PCA analysis that the PAH profiles of the two creeks intermingle. The HCA also confirms the similarity of some samples to urban background as well as coal tar/pitch. The HCA also identified some samples that resemble petroleum fuels.

The HCA and PCA results can be combined by recreating the PCA plot but assigning the colors of the plot symbols based on the HCA clusters (Figure 4). The results show that the HCA clusters are located in the same regions in the PCA plot, indicating concordance between these two computationally distinct methods.

As described in the main Supplemental Data Evaluation (Section 4), sediment toxicity due to porewater PAHs does not correlate well with the absolute PAH concentrations in sediments. This suggests that there is an important relationship between the PAH composition and the trends in the porewater toxic units; specifically, there are different PAH mixtures at the site, and these mixtures have different relative toxicity. Figure 5 again shows the PCA results, but now the shape of the plot symbols denotes the HCA clusters, and the color of the plot symbols denotes the porewater PAH toxic units at that location. Note that porewater was not measured at all locations. Cluster one is exclusively crude oil and fuel oils. The results show that the samples associated with the highest porewater PAH toxic units generally plot along a line and are primarily members of HCA clusters two and three. The distribution of toxic units in each cluster was plotted as a boxplot in Figure 6. These plots clearly show higher porewater toxicity associated with clusters two and three, with toxic unit values greater than ten absent from

clusters four and five. This finding shows that, in general, the samples in clusters four and five exhibited lower toxicity and have a PAH composition different from those with higher toxicity. These results support the hypothesis that certain PAH sources are associated with higher porewater PAH toxicity in Duck and Otter Creeks.

The geography of the samples is important in interpreting both sediment toxicity and PAH sources. Figure 7 presents the sample locations with the colors denoting the HCA clusters. These results show that there is geographic separation between the clusters, and therefore there are geographic trends in the PAH profiles. Specifically, clusters two and three are concentrated in the lower reaches of both Duck and Otter Creeks. Clusters four and five are concentrated in the upper reaches of Duck and Otter Creeks, with another group of samples from these clusters near the confluence of Otter Creek and the Maumee River. In summary, samples belonging to cluster two and three are generally most commonly found in the lower reaches of both Duck and Otter Creek while samples belonging to clusters four and five were found in the upper reaches and at the confluence with the Maumee River.

1.2.2 PAH Ratios

The three ratios discussed above and previously identified by Bobak (2010), FL/FL+PY and BaA/BaA+C0 were calculated and are presented in the biplot shown in Figure 8. The sample points are shaded according to the HCA cluster. The ratios show that the samples with the lowest FL/FL+PY and BaA/BaA+C0 ratios were members of clusters two and three. Higher ratios are associated with clusters four and five. The FL/FL+PY ratios in clusters two and three are generally below 0.4, indicating a petrogenic source. Clusters four and five have ratios indicative of a pyrogenic source.

1.2.3 PAH Composition

The PAH profiles associated with the HCA clusters were calculated based on the average proportion of the total (Figure 9). The spectra show important differences between the clusters. Cluster one is not shown as it is exclusively composed of library samples. Cluster two is enriched in low molecular weight PAHs, especially the naphthalenes. The shape of the C1,C2,C3,C4-napthalene spectra shows enrichment in the alkylated isomers and is consistent with a petrogenic source. This pattern is repeated in the chrysenes and the anthracenes/phenanthracenes. Cluster three is similar to cluster two but is more enriched in the heavier PAHs, and the naphthalene profile is less biased towards the more alkylated groups. Cluster three could be a weathered petrogenic source (e.g., represented by cluster two), as indicated by the loss of naphthalenes and the enrichment in the heavier PAHs. Cluster four exhibits a chrysene profile consistent with pyrogenic sources. This is also true for the anthracenes/phenanthracenes. Cluster four is highly enriched in the high molecular weight PAHs, which is consistent with a pyrogenic source. Cluster five is intermediate. It is relatively enriched in the high molecular weight PAHs and exhibits chrysene profiles consistent with pyrogenic sources. However, the naphthalenes are enriched in the more alkylated isomers, indicating petrogenic inputs. Therefore cluster five is most consistent with a mixture of pyrogenic and petrogenic source (i.e. a mixture of cluster one and cluster three).

The PAH profiles in Figure 9 were compared to the source library samples shown in Figure 10. It is important to note that none of the profiles provide an exact match to the sediment samples.

In fact, the sediment samples are most consistent with mixtures. Clusters four and five show high similarity to urban sediments and coal tar/pitch, with some contribution from fuels such as diesel fuel or coal. Clusters two and three also exhibit a contribution consistent with urban background sediment but have a more substantial contribution from fuels such as diesel. Based on the naphthalene profiles there is little evidence for a contribution from coal in clusters two and three. In summary, clusters two and three are most consistent with petrogenic sources and clusters four and five are most consistent with pyrogenic sources.

1.3 Conclusions

The fingerprinting analysis shows that the sediments in Duck and Otter Creek have been impacted by multiple sources. Each of these sources exhibits a characteristic PAH spectrum and the relative porewater toxicity of these spectra varies. The spectra were analyzed using multiple methods including PCA, HCA, ratio analysis, and geospatial analysis. All of these methods provided consistent conclusions and together provide a consistent picture of the distribution of sediment PAHs. Two primary sources were identified, a petrogenic source typified by lighter PAHs such as naphthalenes and enrichment in the alkylated isomers, and a pyrogenic source.

The analysis identified two unique petrogenic profiles, one of which was more enriched in the heavier PAHs. This heavier second signature, while possibly related to a unique source, is consistent with weathering of the primary source. The most likely primary source is identified as cluster two in the analysis. Cluster three is consistent with weathered cluster two. These two petrogenic data clusters are most commonly found in the lower reaches of both creeks. The porewater toxic units associated with these petrogenic sources tended to be higher, often greater than five.

The two pyrogenic signatures differ with respect to the degree of enrichment of the heavier PAHs. The heaviest profile was identified as cluster four in the analysis. This profile is consistent with urban background and petroleum combustion. Cluster five is enriched in the lighter PAHs, such and naphthalene. In addition, cluster five exhibits some characteristics consistent with a petrogenic contribution. Specifically, cluster five is enriched in the alkylated naphthalenes. In the PCA analysis, cluster five is located between cluster four and the pentrogenic samples in cluster two. The analyses indicate that cluster five, while predominately pyrogenic, is consistent with a mixture of the petrogenic profile of cluster four and the pyrogenic profile of cluster two. The PAH porewater toxic units in the bulk of the samples in clusters four and five were below one, and the samples that exceeded ten were exclusively in clusters two and three.

The fingerprinting analysis shows a unique petrogenic PAH profile in the lower reaches of both creeks. This area has the highest porewater PAH toxic units and therefore is the area with the greatest ecological impacts. The upper reaches of the two creeks and the Meumee River exhibited pyrogenic signature and had the lowest toxic units.

2 References

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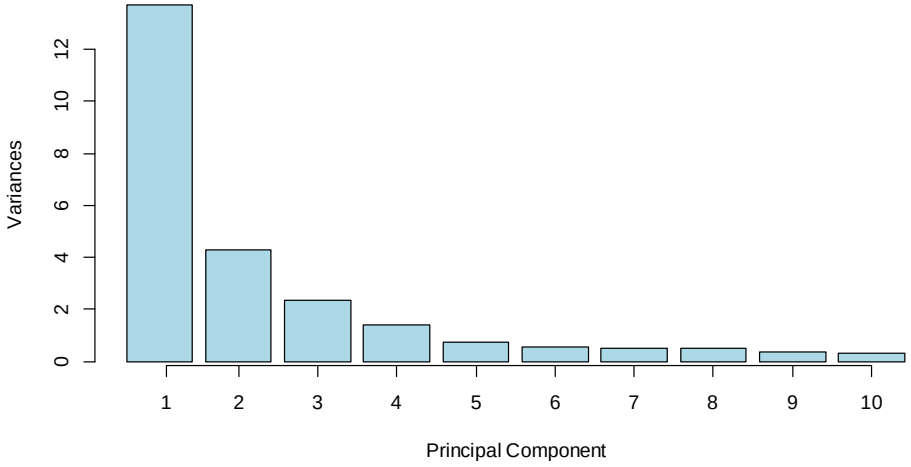
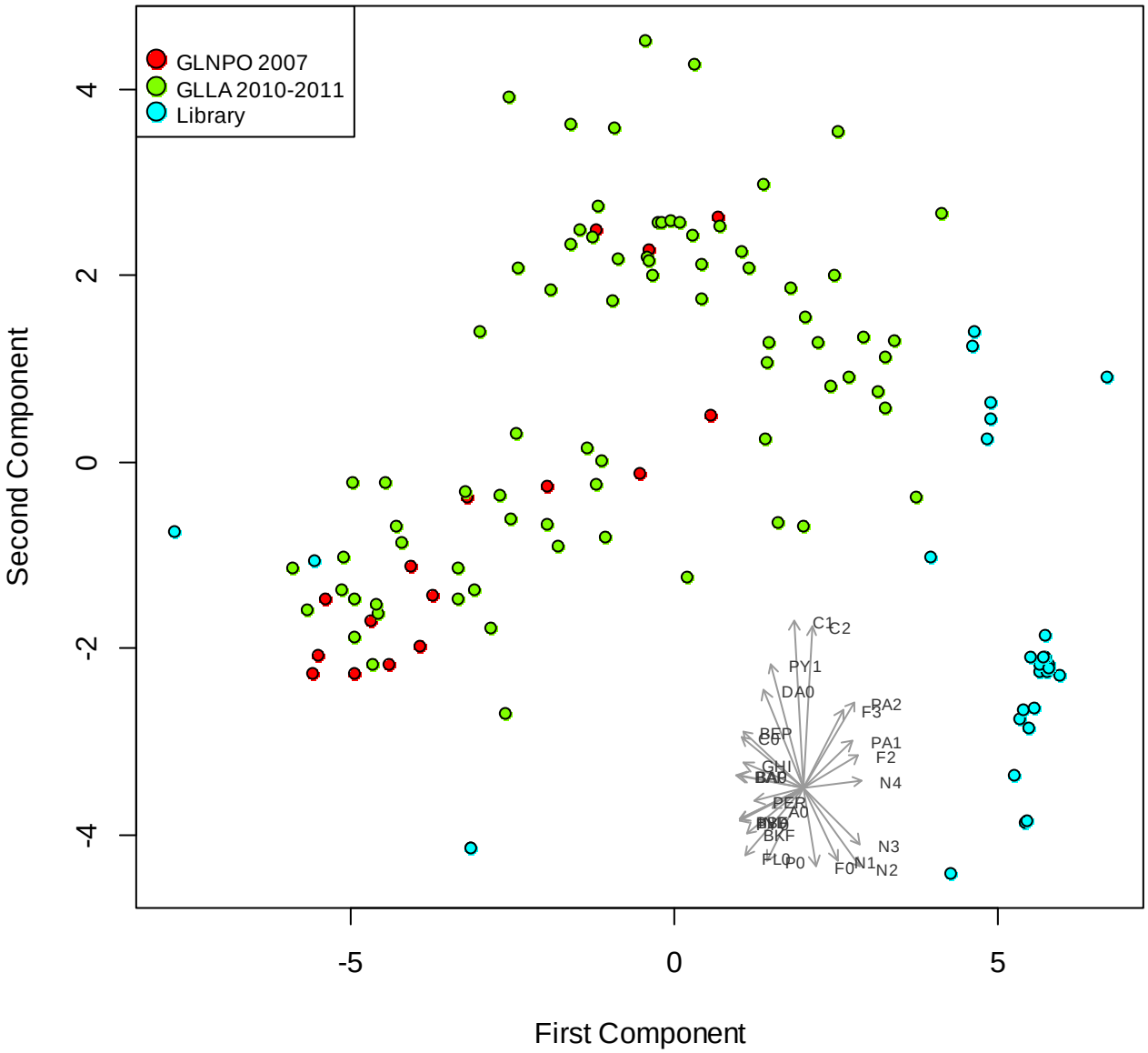
Figures





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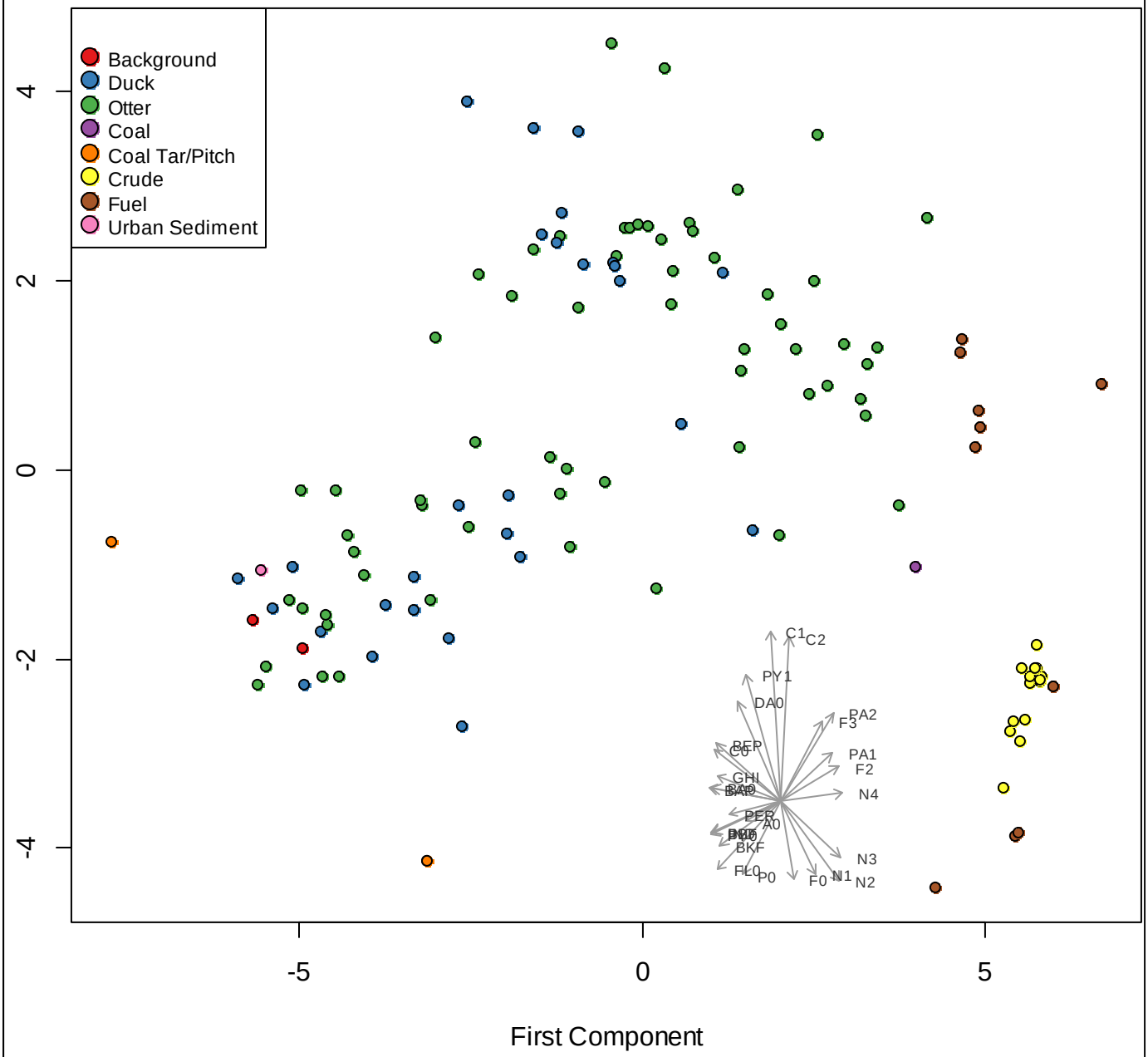
PCA Analysis of Target PAHs

Figure 1



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PCA Analysis of Target PAHs by Location

Figure 2

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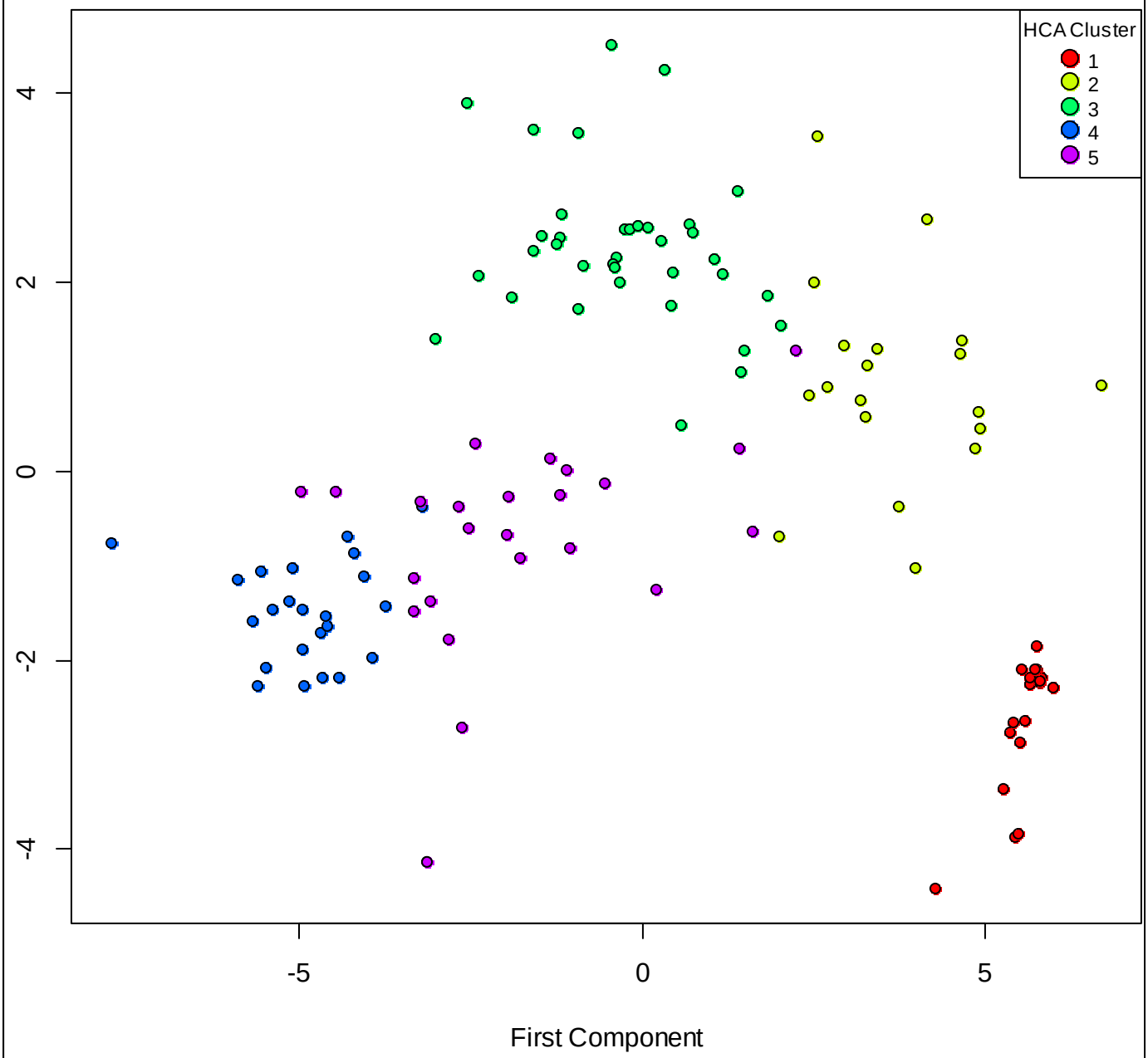
Hierarchal Cluster Analysis of Target PAHs

Figure 3



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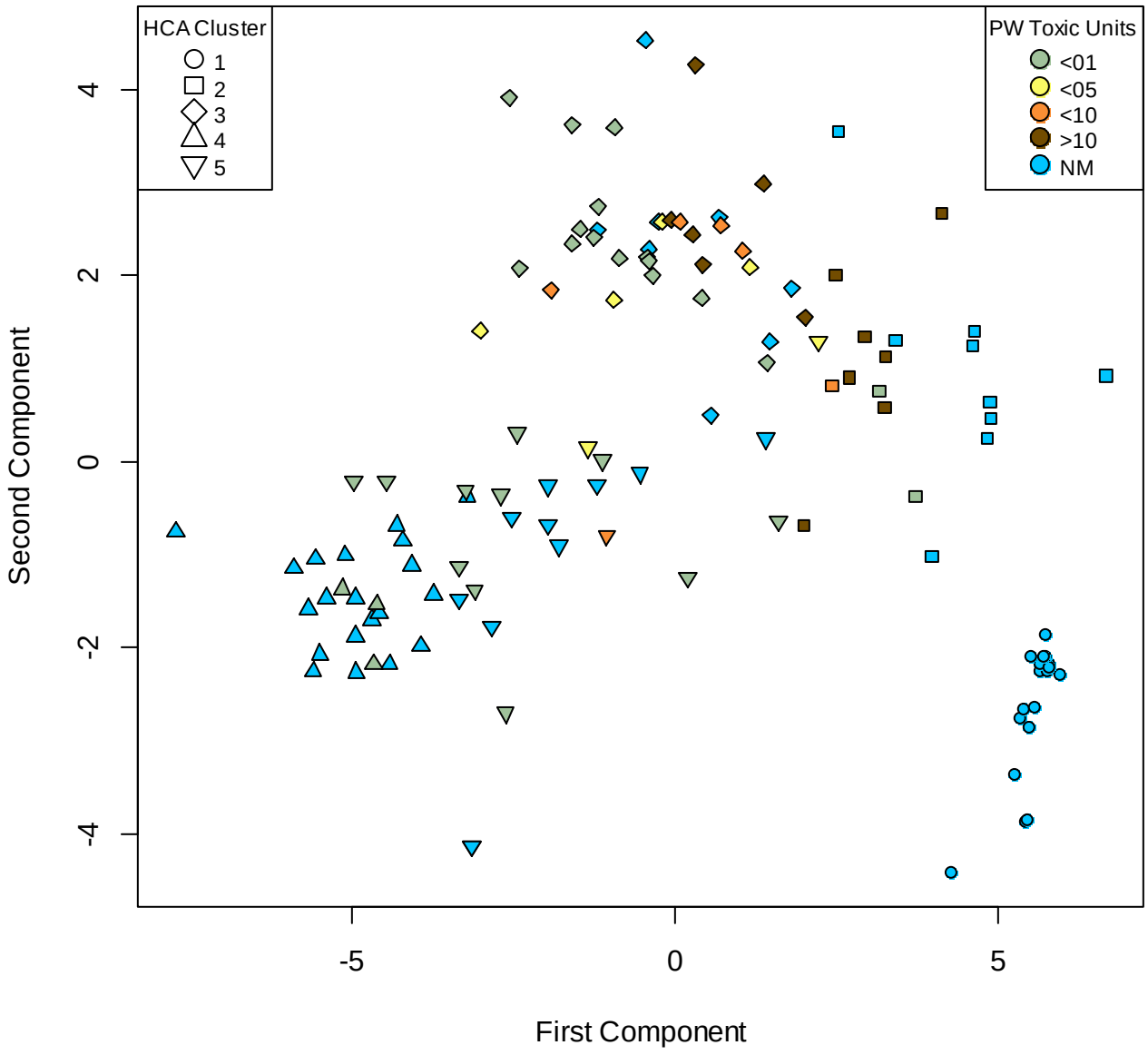
PAH HCA Clusters in PCA Space

Figure 4



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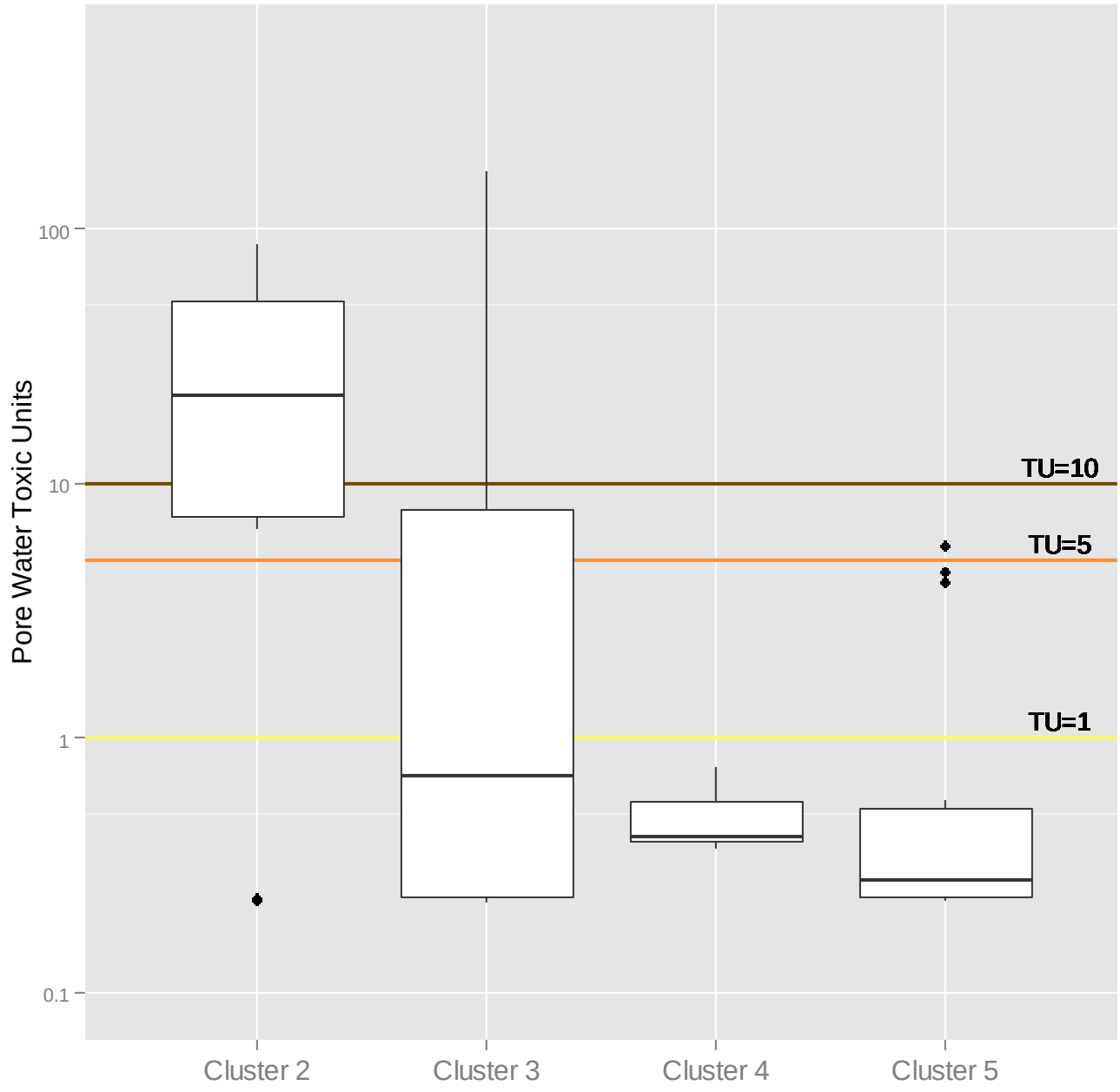
PAH PCA Showing Porewater Toxic Units Results

Figure 5



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Porewater Toxic Units by HCA Cluster

Figure 6

Duck Creek Confluence

Otter Creek

Duck Creek

Otter Creek Confluence

PAH Cluster

- 1
- 2
- 3
- 4
- 5

N
W
E
S

0 0.5 1 Kilometers

Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

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Locations of HCA Clusters

Figure 7

Date: 10/25/2012

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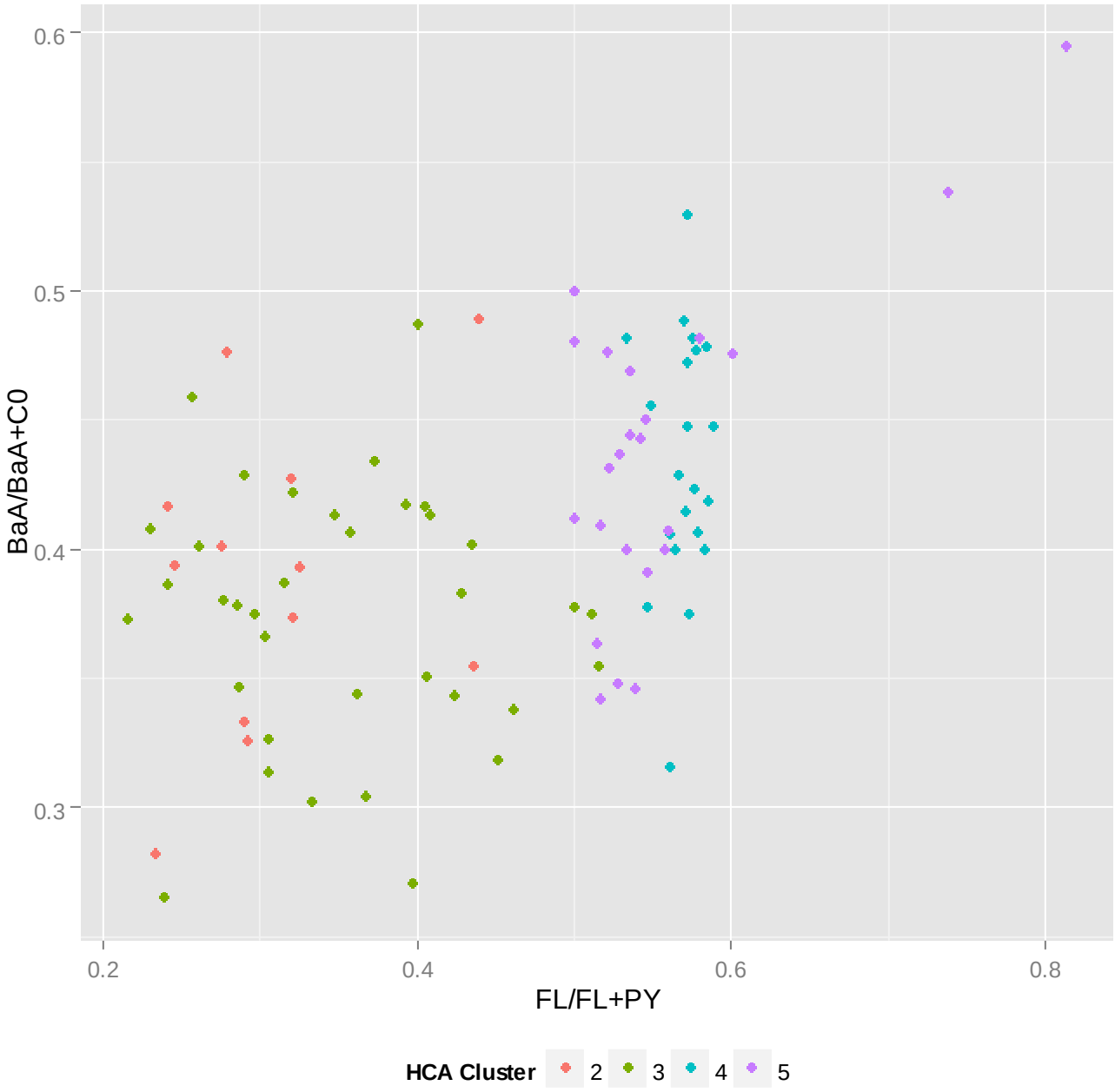

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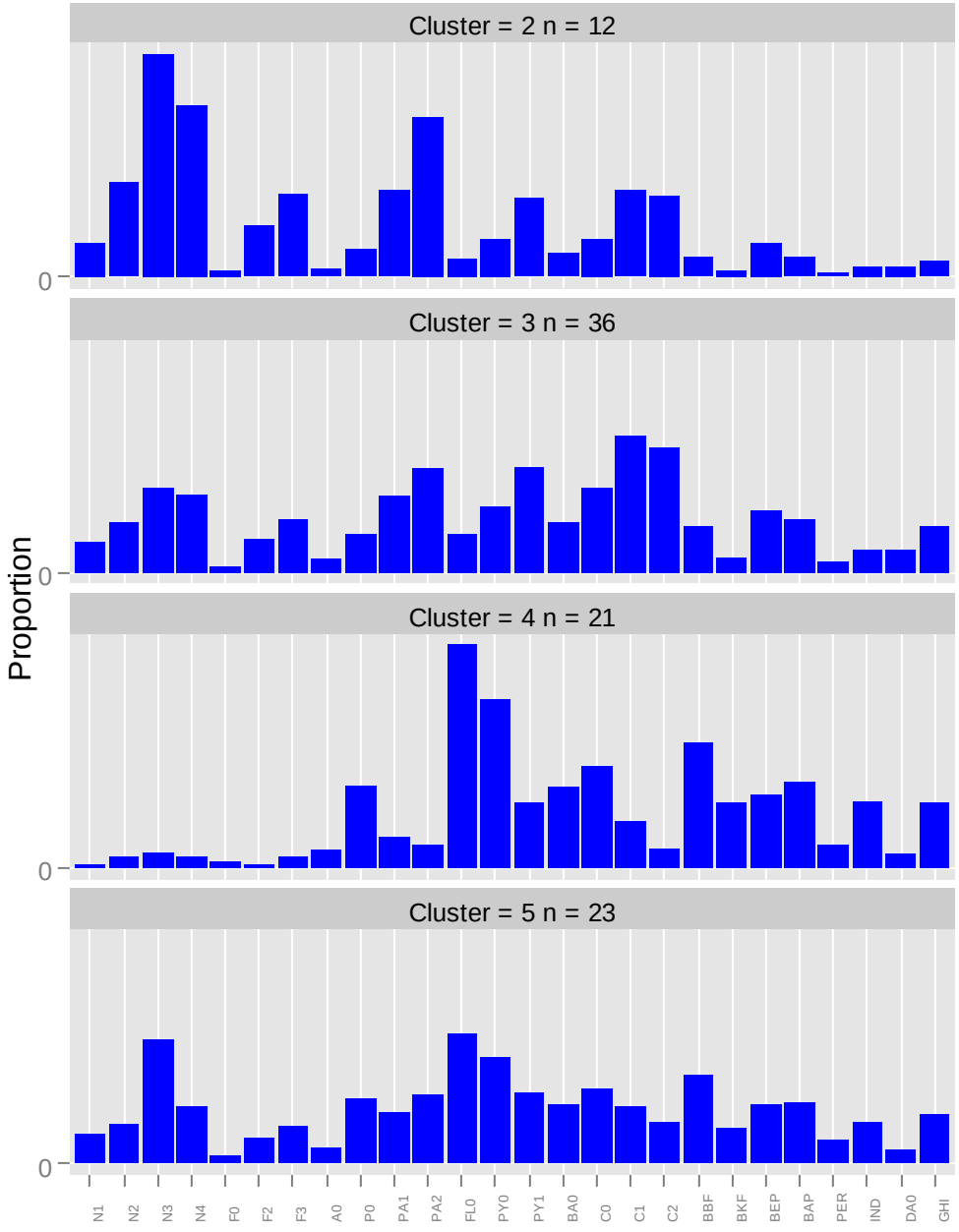
PAH Ratios

Figure 8



Code	PAH
N1	C1-NAPHTHALENES
N2	C2-NAPHTHALENES
N3	C3-NAPHTHALENES
N4	C4-NAPHTHALENES
F0	FLUORENE
F2	C2-FLUORENES
F3	C3-FLUORENES
A0	ANTHRACENE
P0	PHENANTHRENE
PA1	C1-PHENANTHRENES/ANTHRACENES
PA2	C2-PHENANTHRENES/ANTHRACENES
FL0	FLUORANTHENE
PY0	PYRENE
PY1	C1-FLUORANTHENES/PYRENES
BA0	BENZO[A]ANTHRACENE
C0	Chrysene
C1	C1-CHRYSENES
C2	C2-CHRYSENES
BBF	BENZO[B]FLUORANTHENE
BKF	BENZO[K]FLUORANTHENE
BEP	BENZO[E]PYRENE
BAP	BENZO[A]PYRENE
PER	PERYLENE
IND	INDENO[1,2,3-CD]PYRENE
DA0	DIBENZ(A,H)ANTHRACENE
GHI	BENZO[G,H,I]PERYLENE

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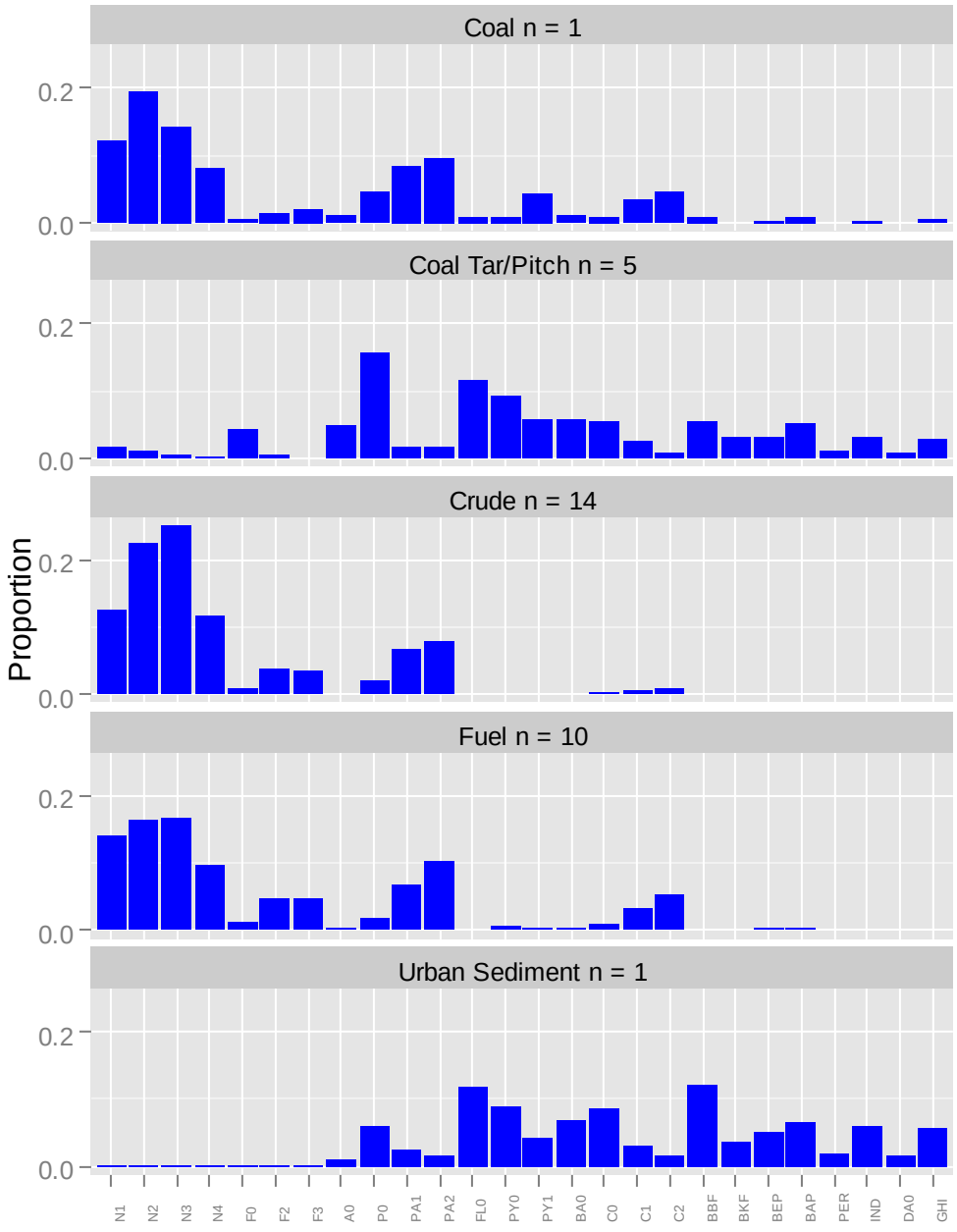
PAH Profiles by HCA Cluster

Figure 9



Code	PAH
N1	C1-NAPHTHALENES
N2	C2-NAPHTHALENES
N3	C3-NAPHTHALENES
N4	C4-NAPHTHALENES
F0	FLUORENE
F2	C2-FLUORENES
F3	C3-FLUORENES
A0	ANTHRACENE
P0	PHENANTHRENE
PA1	C1-PHENANTHRENES/ANTHRACENES
PA2	C2-PHENANTHRENES/ANTHRACENES
FL0	FLUORANTHENE
PY0	PYRENE
PY1	C1-FLUORANTHENES/PYRENES
BA0	BENZO[A]ANTHRACENE
C0	Chrysene
C1	C1-CHRYSENES
C2	C2-CHRYSENES
BBF	BENZO[B]FLUORANTHENE
BKF	BENZO[K]FLUORANTHENE
BEP	BENZO[E]PYRENE
BAP	BENZO[A]PYRENE
PER	PERYLENE
IND	INDENO[1,2,3-CD]PYRENE
DA0	DIBENZ(A,H)ANTHRACENE
GHI	BENZO[G,H,I]PERYLENE

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PAH Profiles by Source Type
(Library Samples)

Figure 10