Phase II GIS-based Sediment Quality Database for the St. Louis River Area of Concern (AOC): Comparison of Surficial Sediment Contamination in the St. Louis River AOC with Other Areas of Concern in the Great Lakes Basin and Other Areas Located Elsewhere in the United States

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1.0 Introduction

The St. Louis River Area of Concern (AOC) is an important transboundary waterway between northeastern Minnesota and northwestern Wisconsin (Figure 1). This AOC contains a number of areas where the concentrations of metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and/or dioxins and furans (PCDDs and PCDFs) are elevated in sediments relative to reference areas. In areas where these substances occur at concentrations sufficient to adversely affect ecological receptors or human health, the sediments are designated as contaminated. The presence of contaminated sediments in this AOC has resulted in a variety of use impairments, including restrictions on dredging, the imposition of fish consumption advisories, and the impairment of benthic habitats for bottom-feeding organisms. In addition, the transport of sediment-derived contaminants to Lake Superior represents a concern for many stakeholders in the region (Crane *et al.* 2000).

The Minnesota Pollution Control Agency (MPCA), Wisconsin Department of Natural Resources (WDNR), Fond du Lac Band, U.S. Army Corps of Engineers, consultants for government agencies and responsible parties, and other federal and academic organizations have conducted a number of investigations to assess sediment quality conditions in the lower St. Louis River AOC, particularly since 1992. As part of the Remedial Action Plan (RAP) process for the St. Louis River AOC, stakeholders identified a need to compile the sediment quality data collected from the St. Louis River in a database format. A matching sediment chemistry and toxicity database was completed in 2000 to support an evaluation of the predictive ability of numerical sediment quality targets (SQTs) in the St. Louis River AOC (Crane *et al.* 2000, 2002a). In 2003, the matching sediment chemistry/toxicity database, as well as additional sediment chemistry, sediment toxicity, bioaccumulation, and physical parameter data collected since 1990 were compiled into the Phase I GIS-based Microsoft™ (MS™) Access 2000 sediment quality database (Smorong and Crane 2003; Smorong *et al.* 2003). Due to the large amount of post-1990 sediment quality data available for the St. Louis River AOC, funding is being obtained by the MPCA and its collaborators in a phased approach to continue the GIS-based sediment quality database. Phase II of the database has recently been completed to include additional sediment quality data from the federal navigation channels and from sites located along the Wisconsin side of this AOC (Smorong and Crane 2004; Smorong *et al.* 2004). The Phase II GIS-based sediment quality database comprises one task of a grant from the U.S. EPA's Great Lakes National Program Office (GLNPO) to develop a comprehensive sediment management plan for the lower St. Louis River AOC (Crane 2004).

With the completion of the Phase II database, an opportunity exists to evaluate the distribution of surficial sediment contaminants within the St. Louis River AOC and to compare these results to the levels of contamination that have been measured at other AOCs in the Great Lakes basin, and in other areas located elsewhere in North America. A similar evaluation was conducted as part of the Phase I GIS-based sediment quality database (MacDonald *et al.* 2003). This memorandum presents the results of analyses that were conducted to facilitate such comparisons and, in so doing, to better understand the severity and potential effects of sediment contamination in the St. Louis River AOC.

2.0 Methods

A step-wise approach was used to compare sediment chemistry data in surficial samples (0-30 cm) from the St. Louis River AOC with that in surficial sediments from other AOCs in the Great Lakes basin and other freshwater or estuarine (salinity less than 10 ppt) areas located elsewhere in North America, including:

- Identifying areas of interest;
- Collating the sediment chemistry data;
- Calculating summary statistics for each geographic area;
- Evaluating the distribution of a mixture of sediment contaminants for each area; and,
- Assessing the potential effects of chemicals of potential concern (COPCs) on benthic invertebrates.

Each of these steps is described in the following sections of this technical memorandum.

2.1 Identification of Areas of Interest

The first step in the evaluation of the level of chemical contamination of surficial sediments in the St. Louis River AOC involved identifying the geographic areas that had enough sediment sample locations to support data analyses. To identify the geographic areas to be included in the analysis, the information contained in the Phase II GIS-based sediment quality database was screened to identify the areas in the St. Louis River AOC for which sediment chemistry data were available for 20 or more surficial sediment samples. Similarly, the information in the geographically-broader SedTox database (a proprietary database owned by MacDonald Environmental Sciences Ltd. and containing matching sediment chemistry and toxicity data from numerous locations in North America; Ingersoll *et al.* 2001) was screened to identify the areas in the Great Lakes basin and elsewhere in North America for which the required quantity of data were available on the chemical characteristics of surficial sediments. The sediment chemistry data that were included in the SedTox database underwent a similar screening procedure to assess data quality as the data sets included in the Phase II GIS-based sediment quality database.

2.2 Collation of Sediment Chemistry Data

To support subsequent data analyses, the available surficial sediment chemistry data for the selected areas of interest were collated. Since a mixture of chemicals are often present in contaminated sediments, mean probable effect concentration quotients (PEC-Qs) were used as an integrative metric for assessing sediment chemistry and sediment quality in each area. The MPCA has adopted consensus-based probable effect concentrations (PECs) for 28 chemicals as Level II sediment quality targets (SQTs) for the St. Louis River AOC (Crane *et al.* 2000, 2002a). These mean PEC-Qs were calculated using the procedures recommended by USEPA (2000) and outlined in Crane *et al.* (2000, 2002a) for the integration of total PAHs, total PCBs, and selected metals. This procedure differs from the one that was used previously to calculate mean PEC-Qs for Minnesota Slip in the Duluth Harbor (Crane *et al.* 2002b) and, thus, yields somewhat different results. The mean PEC-Q data for the selected areas of interest were extracted from the two databases and compiled in MS™ Excel spreadsheets to support subsequent data analyses.

2.3 Calculation of Summary Statistics

The distribution of mean PEC-Qs was determined for the St. Louis River AOC, for other AOCs within the Great Lakes basin, and for other areas located elsewhere in North America. The distributions of mean PEC-Qs were determined for each of the selected areas of interest by calculating a series of summary statistics, including the arithmetic mean and standard deviation, as well as minimum, 10^{th} percentile, median, 90^{th} percentile, and maximum values. These summary statistics were considered to provide reasonable estimates of the central tendency, variation, and position of the underlying data.

2.4 Evaluation of the Distribution of the Mean PEC-Qs

In addition to calculating summary statistics, the distribution of the mean PEC-Q data for each of the selected areas of interest was illustrated through the preparation of box and whisker plots and cumulative distribution frequency (CDF) plots. The box and whisker plots were generated using the statistical software program SigmaPlot Version 6. Box and whisker plots present data as a box representing statistical values. The boundary of the box closest to zero indicates the 25^{th} percentile, a line within the box marks the median, and the boundary of the box farthest from zero indicates the 75^{th} percentile. Whiskers above and below the box indicate the 10^{th} and 90^{th} percentiles, respectively. The CDF plots were also generated using SigmaPlot Version 6. In these plots, the mean PEC-Q values are the independent variable (x-axis). The number of stations for each area are normalized to 100 (% stations) and represented on the y-axis.

2.5 Assessment of the Potential Effects of Contaminated Sediments

Sediment-associated contaminants have the potential to adversely affect a variety of aquatic receptors, including microbiota, aquatic plants, benthic invertebrates, and fish. Although the State of Minnesota has not established toxicity thresholds for whole sediments for most of these receptor groups, the MPCA adopted sediment quality targets (i.e., Level I and Level II SQTs) for the St. Louis River AOC that are intended to support assessments of the potential effects of contaminated sediments on benthic invertebrates

(Crane *et al.* 2000, 2002a; Crane and MacDonald 2003). The Level I SQTs are intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms are unlikely to occur. Crane *et al.* (2000) recommended a Level I SQT of 0.1 for mean PEC-Qs. The Level II SQTs are intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms are likely to occur frequently or always. Crane *et al.* (2000) recommended a Level II SQT of 0.6 for mean PEC-Qs. These SQTs were used to evaluate the potential effects of contaminated sediments on benthic invertebrates in the selected areas of interest. The Wisconsin Department of Natural Resources has also adopted the consensus-based sediment quality guidelines (MacDonald *et al*. 2000) for which most of the Level I and Level II SQTs are based on. However, they do not distinguish recommended levels of mean PEC-Qs in their guidance (WDNR 2003).

To facilitate the evaluation of the potential for observing adverse effects on benthic invertebrates within the selected areas of interest, the sediment samples for each geographic area were divided into three groups. Samples with mean PEC-Qs below 0.1 were included in a low risk group. Samples with mean PEC-Qs of $\geq$0.1 and $\leq$ 0.6 were included in a moderate risk group, while those with mean PEC-Qs of > 0.6 were included in a high risk group. Subsequently, the number of samples in each group and the percentage of the total number of samples available for that area of interest that the number represented were calculated.

3.0 Results and Discussion

3.1 Areas of Interest in the St. Louis River AOC and Elsewhere

The Phase II MS™ Access 2000 sediment quality database for the St. Louis River AOC contains data on the concentrations of COPCs for a total of 567 surficial sediment samples from 36 reaches within the AOC. Of these reaches, 10 had sufficient data (i.e., $\geq$ 20 sediment samples) on the chemical characteristics of surficial sediments to support subsequent data analyses, including the Interlake/Duluth Tar Superfund site, Minnesota Slip, Slip C, the embayment encompassing the Western Lake Superior Sanitory District

(WLSSD) and Coffee and Miller Creeks, lower St. Louis River, Thomson Reservoir, Superior Bay, Koppers Industries Inc. site, Hog Island Inlet/Newton Creek, and Howard's Bay. Insufficient data were available to support the assessment of sediment quality conditions in several other areas of interest that are known or suspected to contain elevated levels of COPCs, including the USS Superfund site, the City of Superior wastewater treatment plant, Fond du Lac Reservoir, and Forbay Reservoir. Additional data from the Minnesota side of the AOC will be added to a subsequent update of the GIS-based database (i.e., Phase III) to be initiated in October 2004. Therefore, the results of the analyses conducted in this investigation should not be considered to provide a comprehensive basis for assessing sediment quality conditions in the St. Louis River AOC. In addition, other sediment quality indicators (e.g., sediment toxicity, benthic invertebrate community structure, tissue chemistry) should also be considered in evaluations of sediment quality.

To provide a basis for comparison with the St. Louis River AOC, the SedTox database was also searched to obtain surficial sediment chemistry data for other AOCs in the Great Lakes basin and for other areas located elsewhere in North America. Based on the screening criteria that were established for this investigation (i.e., availability of surficial sediment chemistry data for at least 20 sediment samples), a total of seven additional Great Lakes AOCs were selected for inclusion in the analyses. These areas of interest included: Grand Calumet River AOC, IN; Maumee River AOC, OH; St. Mary's River AOC, ON and MI; Waukegan Harbor AOC, IL; Cuyahoga River AOC, OH; Oswego River AOC, NY; and St. Clair River AOC, ON and MI. Insufficient data were available for the Sheboygan Harbor AOC to include it in the analysis, once lower quality data were removed from the database. Six areas of interest from outside the Great Lakes basin were also selected for evaluation in this investigation, including: Willamette River, OR; Anacostia River, DC; Calcasieu River, LA; Lower Savannah River, GA; Homestead Air Force Base, FL; and Trinity River, TX.

3.2 Distributions of Sediment Chemistry Data

The distributions of the sediment chemistry data for the selected areas of interest were evaluated in three ways, including the calculation of summary statistics, the preparation of box and whisker plots, and the development of CDF plots. The summary statistics that were used to describe the distribution of mean PEC-Qs for the selected areas of interest within the St. Louis River AOC are presented in Table 1 and plotted in Figure 2 and 3. These results show that, on average, the highest levels of sediment contamination occurred at the Koppers Industries, Inc. site (average and maximum mean PEC-Qs of 109 and 2330, respectively; n=42) and the Interlake/Duluth Tar Superfund site (average and maximum mean PEC-Qs of 7.62 and 72.2, respectively; n=20). Elevated levels of COPCs were also observed in surficial sediments from Minnesota Slip and Slip C [i.e., average mean PEC-Qs of 1.03 (n=39) and 0.553 (n=29), respectively]. Relatively lower average mean PEC-Qs (i.e., 0.137 to 0.342) were measured in the other six areas of interest within the St. Louis River AOC (n=22 to 103). Overall, the mean PEC-Qs for surficial sediments from the St. Louis River AOC averaged 8.68 and ranged from 0.00764 to 2330 (n=567). However, the median of the mean PEC-Q values for the entire AOC was 0.198 (Table 1). As indicated by the high standard deviation in the average mean PEC-Qs for the Koppers Industries Inc. site (SD = 390) and for the entire St. Louis River AOC (SD = 109), contaminant concentrations vary substantially, both within and among reaches. Accordingly, then, these high standard deviations may limit the value of the arithmetic mean as an accurate estimate of central tendency, particularly when multiple areas are being compared. In addition, average values of mean PEC-Qs may not necessarily provide an accurate estimate of the distribution of the data when sediment chemistry data from stratified random and gradient-type designs are included in the data sets for these areas of interest. Therefore, comparisons between the St. Louis River AOC with other areas in the Great Lakes basin and United States will be based on the median of the mean PEC-Qs for each area.

The levels of COPCs in surficial sediments from AOCs elsewhere in the Great Lakes basin were highly variable (Table 2; Figures 4 and 5). Among the AOCs considered, the greatest range of mean PEC-Qs (0.000636 to 23,800, n=821) was observed in surficial sediments from the Grand Calumet River AOC. Five other AOCs had higher median values of the mean PEC-Qs than observed for the St. Louis River AOC, including the Grand Calumet River AOC (2.49, n=821), St. Mary's River AOC (1.02, n=38), Cuyahoga River AOC (0.939, n=21), Waukegan Harbor AOC (0.518, n=23), and Maumee River AOC (0.278, n=25). The median of the mean PEC-Q values for the St. Clair River AOC

(0.153, n=44) and Oswego River AOC (0.0763, n=22) were lower than for the St. Louis River.

Among the areas of interest located outside the Great Lakes basin, the Willamette River in Oregon showed the greatest range of chemical contamination (Table 3; Figures 6 and 7). Mean PEC-Qs for the surficial sediment samples from this location ranged from 0.00671 to 190 (n=60). The median of the mean PEC-Qs was greater for the Anacostia River, DC (0.517, n=53), Willamette River, OR (0.487, n=60), and Lower Savannah River, GA (0.298, n=48) than for the St. Louis River AOC (0.198, n=567). The other three geographic areas included in this analysis had median values of the mean PEC-Qs that were less than that observed in the St. Louis River AOC, including the Calcasieu River, LA (0.181, n=631), Trinity River, TX (0.166, n=64), and Homestead Airforce Base, FL (0.0865, n=88).

3.3 Potential Effects of Contaminated Sediments on Benthic Invertebrates

The risks to the benthic invertebrate community posed by exposure to contaminated sediments in the St. Louis River AOC were evaluated using the Level I and Level II SQTs that were adopted for use in Minnesota (Crane *et al.* 2000, 2002a). More specifically, risks to benthic invertebrates were considered to be low if mean PEC-Qs were <0.1, moderate if mean PEC-Qs were between 0.1 and 0.6, and high if mean PEC-Qs were >0.6. Based on the results of these analyses (Table 4), whole sediment samples collected in the vicinity of the Interlake/Duluth Tar Superfund site and Minnesota Slip appear to pose the highest risks to benthic invertebrates. Approximately 85% and 90% of the samples from the Interlake/Duluth Tar Superfund site and the Minnesota Slip site, respectively, had mean PEC-Qs of >0.6. However, the magnitude of the exceedance of the Level II SQT was more than a factor of ten greater at the Interlake/Duluth Tar Superfund site than for Minnesota Slip. The frequency of high risk samples tended to be lower at the other eight areas considered, ranging from 0% for the Thomson Reservoir and Superior Bay to 57% for the Koppers Industries, Inc. site. Overall, 18% of the surficial sediment samples from the St. Louis River AOC had concentrations of total PAHs (based on the 13 parent low molecular weight and high molecular weight PAHs), total PCBs, and/or metals (i.e., arsenic, cadmium, chromium, copper, lead, nickel, and/or zinc) sufficient to pose high risks to benthic invertebrates. The majority (56%) of surficial sediment samples in the St. Louis River AOC were associated with moderate risk to benthic invertebrates, whereas 26% of samples were of low risk to benthic invertebrates (Table 4).

Among the seven Great Lakes AOCs considered, three AOCs had mean PEC-Qs sufficient to pose high risks to benthic invertebrates in at least 60% of the sediment samples collected from each respective site (Table 4). These AOCs included the Cuyahoga River AOC (76% of samples), the Grand Calumet River AOC (70% of samples), and the St. Mary's River AOC (61% of samples). Lower frequencies of high risk samples were observed for the Waukegan Harbor AOC (35% of samples), Maumee River AOC (28% of samples), St. Clair River AOC (5% of samples), and Oswego River AOC (0% of samples). The Oswego River AOC had the greatest percentage of samples (68%) with mean PEC-Qs <0.1, followed by the St. Clair River AOC (25%). The frequency of low, moderate, and high risk samples in the St. Clair River AOC was the most similar of the other Great Lakes AOCs to the distribution observed in the St. Louis River AOC.

Among the areas located elsewhere in the United States, the frequency of high risk samples tended to be lower than was observed for the other Great Lakes AOCs (Table 4). The highest frequency of high risk samples was observed for the Anacostia River (40% of samples) and the Willamette River (43% of samples). The potential for observing adverse effects was much lower for the other four areas considered, ranging from 0% high risk samples for the Trinity River and Lower Savannah River to 8% high risk samples for the Homestead Airforce Base. Of the six areas considered, only the Anacostia River and Willamette River had frequencies of high risk samples higher than the frequency that was determined for the St. Louis River AOC. Homestead Airforce Base had the greatest percentage of samples with mean PEC-Qs <0.1 (i.e., 56%), followed by the Calcasieu River (18%). Over 50% of the samples at five of the six geographic areas considered had surficial sediments that were sufficiently contaminated to pose a moderate risk to benthic invertebrates.

While these statistical analyses provide a useful screening assessment of sediment quality conditions in the surficial sediments of numerous areas in North America, these analyses must be considered in the context of the following uncertainties:

- The databases used for these analyses were not inclusive of all the surficial sediment chemistry data available for the areas of interest, but were nevertheless assumed to be representative of the available data. Therefore, these analyses should be updated as the GIS-based sediment quality database for the St. Louis River AOC and the SedTox databases are updated and expanded. In addition, similar analyses could be done using the GIS-based sediment quality database and the U.S. EPA's National Sediment Inventory when it becomes publicly available.
- The mean PEC-Qs may not include all COPCs for a particular area. For example, diesel range organics and a number of other PAHs contribute to ecological risk at the Hog Island Inlet/Newton Creek site in the St. Louis River AOC (SEH Inc. 2003a,b), and mercury is an important COPC at many contaminated sediment sites across North America.
- Use of the mean PEC-Qs should take into consideration variations in physical, chemical, and biological factors in the sediment environment that may complicate and introduce uncertainty into their use. For example, certain chemicals can be present in relatively unavailable forms (such as in slag, paint chips, and tar). Use of the mean PEC-Qs may not be applicable in depositional wetlands (due to high organic matter and sulfides), oil and gas production environments, in highly modified depositional systems, and in nondepositional and erosional systems (Wenning and Ingersoll 2002).
- Sediments are often heterogeneous, resulting in patchy distributions of contaminants, grain size, sulfide levels, and organic carbon type at varying levels of scale.
- Use of the mean PEC-Qs is enhanced when considered as part of a weight-of-evidence approach that includes other sediment quality indicators, such as sediment chemistry and geochemical characteristics, sediment toxicity, and benthic invertebrate community structure.
- Due to uncertainties associated with bioavailability, there is not a 100% certainty that samples with mean PEC-Qs exceeding 0.6 will actually be toxic to sediment-dwelling organisms. Rather, the probability of observing chronic toxicity to amphipods (*Hyalella azteca*) in 28-day exposures is greater than 50% when mean PEC-Qs exceed a mean PEC-Q of 0.63 (USEPA 2000; Ingersoll *et al.* 2001). In the St. Louis River AOC, the incidence of toxicity to

amphipods and midges (conducted as separate 10-day sediment toxicity tests) was found to increase as the mean PEC-Q ranges increased (Crane *et al.* 2002a).

None of the aforementioned factors, though, preclude the general application of the mean PEC-Qs to the analyses conducted in this assessment.

4.0 Conclusions

The available surficial sediment chemistry data from the St. Louis River AOC, other AOCs in the Great Lakes basin, and other geographic areas in North America were queried, compiled, and compared from two different sediment quality databases. To facilitate comparisons of these data, mean PEC-Qs were calculated for each surficial sediment sample represented in the Phase II GIS-based sediment quality database for the St. Louis River AOC and in the SedTox database. The results of this evaluation indicated that sediment quality conditions in the St. Louis River AOC varied widely. Twenty-six percent of samples in the St. Louis River AOC were associated with low risk (i.e., mean PEC-Qs of <0.1), 56% of samples were associated with moderate risk (i.e., mean PEC-Qs of 0.1 to 0.6), and 18% of samples were associated with high risk to sediment-dwelling organisms (i.e., mean PEC-Qs of >0.6). Among the reaches for which sufficient data were available to conduct data analyses, the Interlake/Duluth Tar Superfund site and Minnesota Slip had the highest levels of contamination, primarily from PAHs. More than 80% of the samples collected at each site exceeded the mean PEC-Qs of 0.6, indicating that contaminated surficial sediments pose high risks to the benthic invertebrate community at both sites. Slip C and the Koppers Industries, Inc. site also had relatively high frequencies of exceedence of the Level II SQT (i.e., 34% and 57%, respectively).

Among the Great Lakes AOCs that were considered, the highest levels of chemical contamination were observed in surficial sediments from the Grand Calumet River AOC. While the median of the mean PEC-Q values were much higher at this AOC than at the other AOCs included in this assessment, conditions sufficient to adversely affect sediment-dwelling organisms (i.e., mean PEC-Qs >0.6) were frequently observed in many of the

AOCs considered, except for the St. Clair River and Oswego River AOCs. Based on the median of the mean PEC-Q values calculated, the St. Louis River AOC ranked sixth in terms of chemical contamination among the eight AOCs considered in this analysis.

Among the six other geographic areas in the United States that were considered in this analysis, the highest levels of contamination were observed in sediment samples from the Willamette River, OR. Much lower levels of contamination were observed at the five other sites. Based on the median of the mean PEC-Q values calculated, the St. Louis River AOC ranked fourth in terms of chemical contamination among the areas located outside the Great Lakes basin. When both the Great Lakes AOCs and other areas in the United States were considered, the St. Louis River AOC ranked ninth highest among the 14 areas in terms of the medians of the mean PEC-Q values.

The statistical evaluation conducted for this study provided a useful comparison of sediment quality conditions, in the form of mean PEC-Qs, between the St. Louis River AOC and other AOCs in the Great Lakes basin and the rest of the United States. Interpretation of the results of this screening assessment should be made in the context of the uncertainties identified for this analysis. As additional updates are made to the GIS-based sediment quality database for the St. Louis River AOC and other national and North American sediment quality databases, similar analyses may be conducted to compare sediment quality conditions between sites.

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Table 1. Distribution of mean PEC-Qs in surficial sediments for selected areas in the St. Louis River Area of Concern (AOC).

Reach/Site	n	Arithmetic Mean	Standard Deviation	Minimum	10th percentile	Median	90th percentile	Maximum
Koppers Industries Inc. Site	42	109	390	0.0432	0.0574	1.91	197	2330
Interlake/Duluth Tar Superfund Site	20	7.62	16.6	0.249	0.536	1.40	16.8	72.2
Minnesota Slip	39	1.03	0.402	0.147	0.630	0.988	1.56	1.89
Slip C	29	0.553	0.393	0.0571	0.130	0.496	1.11	1.52
Howard's Bay	34	0.342	0.151	0.0644	0.159	0.340	0.529	0.686
WLSSD, Miller Creek and Coffee Creek Embayment	27	0.331	0.167	0.0595	0.122	0.335	0.475	0.760
Lower St. Louis River	31	0.328	0.672	0.0113	0.0460	0.148	0.484	3.78
Hog Island Inlet/Newton Creek	103	0.280	0.260	0.00764	0.0749	0.236	0.455	1.62
Superior Bay	59	0.152	0.0978	0.00942	0.0237	0.153	0.276	0.397
Thomson Reservoir	22	0.137	0.0423	0.0772	0.0858	0.146	0.170	0.261
St. Louis River AOC	567	8.68	109	0.00764	0.0473	0.198	1.21	2330

WLSSD = Western Lake Superior Sanitary District.

Table 2. Distribution of mean PEC-Qs in surficial sediments for selected Great Lakes Areas of Concern (AOCs).

Area of Concern	n	Arithmetic Mean	Standard Deviation	Minimum	10th percentile	Median	90th percentile	Maximum
Grand Calumet River AOC	821	54.1	867	0.000636	0.123	2.49	25.2	23800
St. Louis River AOC	567	8.68	109	0.00764	0.0473	0.198	1.21	2330
Maumee River AOC	25	8.09	35.8	0.162	0.172	0.278	4.05	180
St. Mary's River AOC	38	5.58	11.1	0.0412	0.199	1.02	15.4	52.4
Cuyahoga River AOC	21	1.08	0.748	0.420	0.489	0.939	1.54	3.92
Waukegan Harbor AOC	23	0.575	0.249	0.250	0.380	0.518	0.920	1.30
St. Clair River AOC	44	0.398	1.44	0.0440	0.0720	0.153	0.390	9.66
Oswego River AOC	22	0.0941	0.0545	0.0196	0.0431	0.0763	0.176	0.226

Table 3. Distribution of mean PEC-Qs in surficial sediments for selected areas elsewhere in North America.

Geographic Area	n	Arithmetic Mean	Standard Deviation	Minimum	10th percentile	Median	90th percentile	Maximum
Willamette River, OR	60	10.8	33.6	0.00671	0.188	0.487	15.0	190
St. Louis River AOC	567	8.68	109	0.00764	0.0473	0.198	1.21	2330
Anacostia River, DC	53	0.710	0.594	0.0209	0.252	0.517	1.67	2.76
Calcasieu River, LA	631	0.497	3.30	0.0118	0.0729	0.181	0.514	56.8
Lower Savannah River, GA	48	0.289	0.0835	0.112	0.173	0.298	0.384	0.454
Homestead Airforce Base, FL	88	0.198	0.256	0.0114	0.0364	0.0865	0.478	1.41
Trinity River, TX	64	0.180	0.0797	0.0643	0.102	0.166	0.269	0.552

Table 4. Frequency of low, moderate, and high risk samples for the St. Louis River Area of Concern (AOC), other AOCs in the Great Lakes basin, and other areas located in North America.

Area/Reach	n	Number (%) of Samples Within Ranges of Mean PEC-Qs					
		<0.1		0.1 to 0.6		>0.6	
St. Louis River AOC							
Koppers Industries Inc. Investigation Area	42	9	(21%)	9	(21%)	24	(57%)
Interlake/Duluth Tar Superfund Site	20	0	(0%)	3	(15%)	17	(85%)
Minnesota Slip	39	0	(0%)	4	(10%)	35	(90%)
Slip C	29	3	(10%)	16	(55%)	10	(34%)
Howard's Bay	34	1	(3%)	31	(91%)	2	(6%)
WLSSD, Miller Creek & Coffee Creek Embayment	27	2	(7%)	23	(85%)	2	(7%)
Lower St. Louis River	31	13	(42%)	15	(48%)	3	(10%)
Hog Island Inlet/Newton Creek	103	17	(17%)	81	(79%)	5	(5%)
Superior Bay	59	22	(37%)	37	(63%)	0	(0%)
Thomson Reservoir	22	6	(27%)	16	(73%)	0	(0%)
St. Louis River AOC Overall	567	147	(26%)	318	(56%)	102	(18%)
Other Great Lakes AOCs							
Grand Calumet River AOC	821	57	(7%)	192	(23%)	572	(70%)
Maumee River AOC	25	0	(0%)	18	(72%)	7	(28%)
St. Mary's River AOC	38	3	(8%)	12	(32%)	23	(61%)
Cuyahoga River AOC	21	0	(0%)	5	(24%)	16	(76%)
Waukegan Harbor AOC	23	0	(0%)	15	(65%)	8	(35%)
St. Clair River AOC	44	11	(25%)	31	(70%)	2	(5%)
Oswego River AOC	22	15	(68%)	7	(32%)	0	(0%)
Other Areas in North America							
Willamette River, OR	60	1	(2%)	33	(55%)	26	(43%)
Anacostia River, DC	53	1	(2%)	31	(58%)	21	(40%)
Calcasieu River, LA	631	111	(18%)	476	(75%)	44	(7%)
Lower Savannah River, GA	48	0	(0%)	48	(100%)	0	(0%)
Homestead Airforce Base, FL	88	49	(56%)	32	(36%)	7	(8%)
Trinity River, TX	64	6	(9%)	58	(91%)	0	(0%)

WLSSD = Western Lake Superior Sanitary District.

Figure 1. Map showing surficial sampling locations and reaches within the St. Louis River AOC.

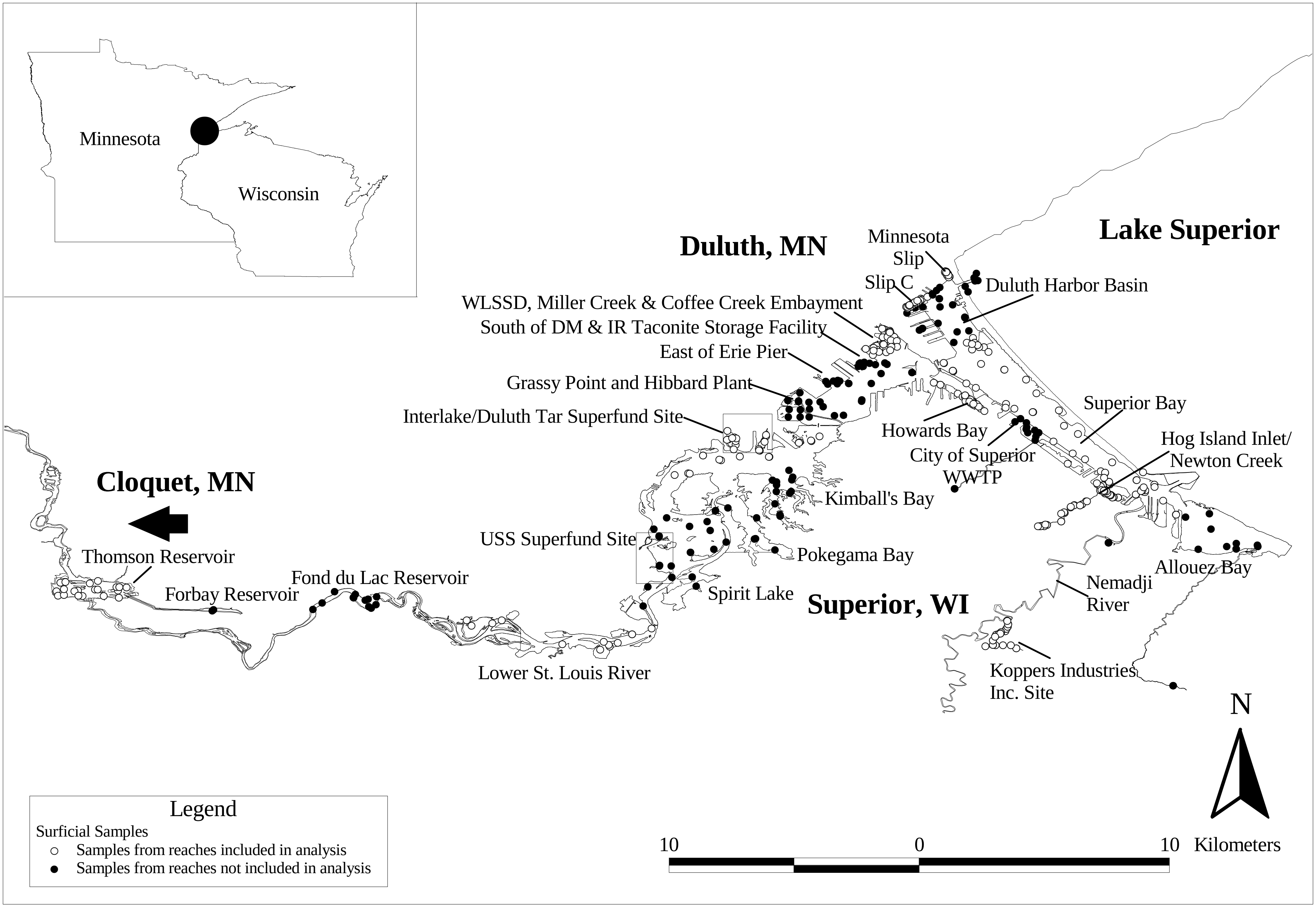

Figure 2. Box and whisker plot showing mean PEC-Q distribution for selected reaches in the St. Louis River AOC.

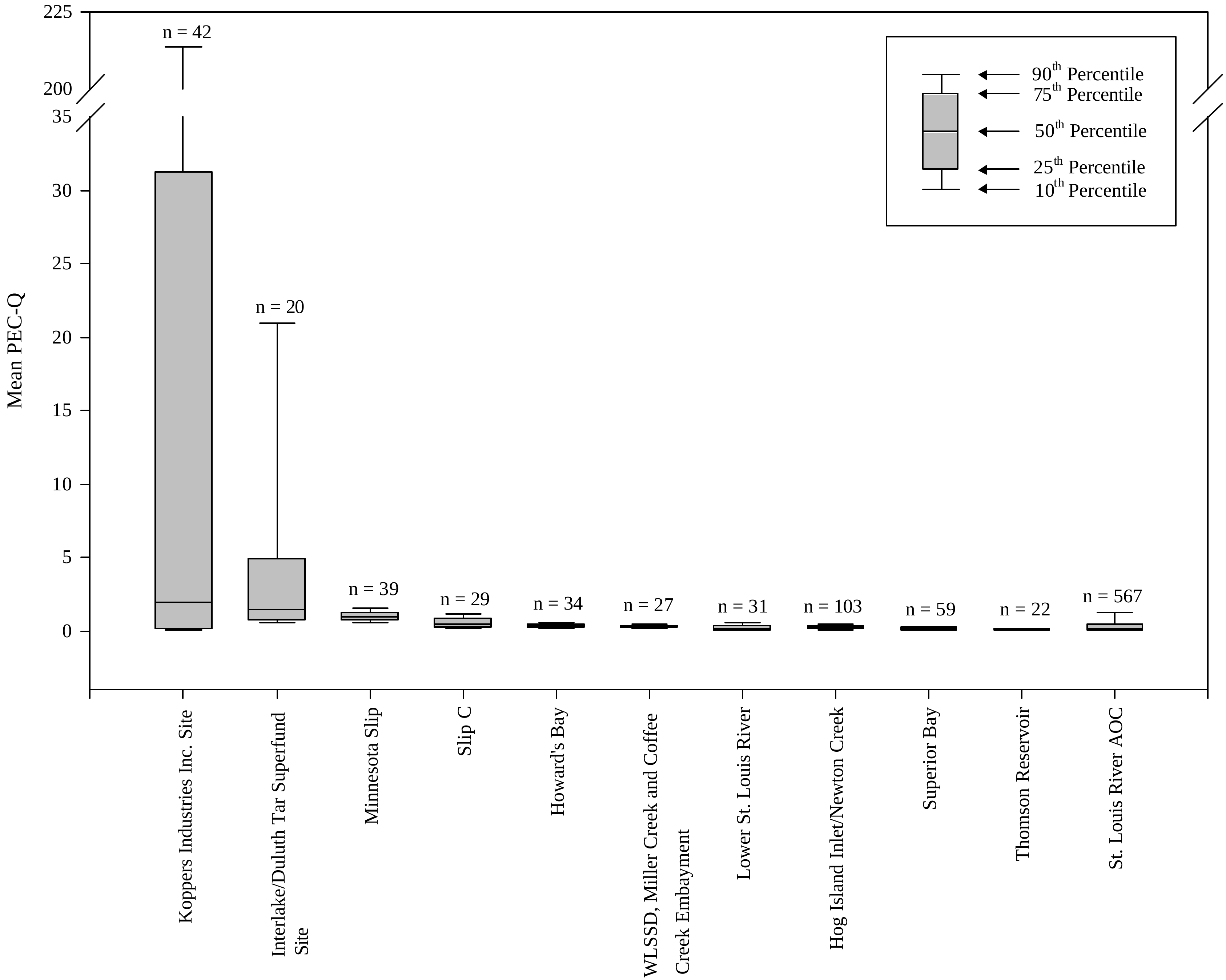

Figure 3. Cumulative distribution frequencies of mean PEC-Qs for surficial sediment samples from selected reaches of the St. Louis River AOC.

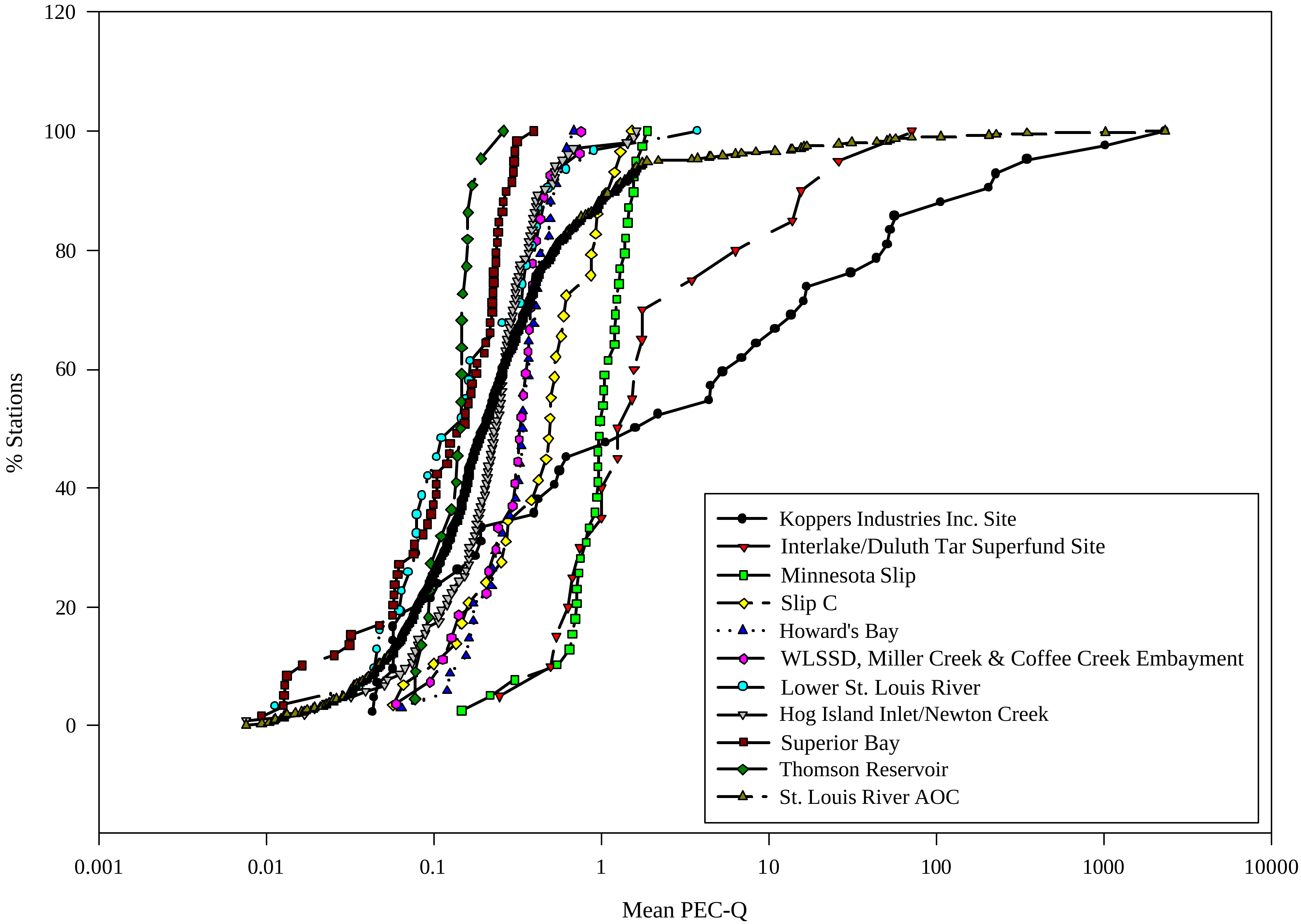

Figure 4. Box and whisker plots showing mean PEC-Q distribution for selected Great Lake AOCs.

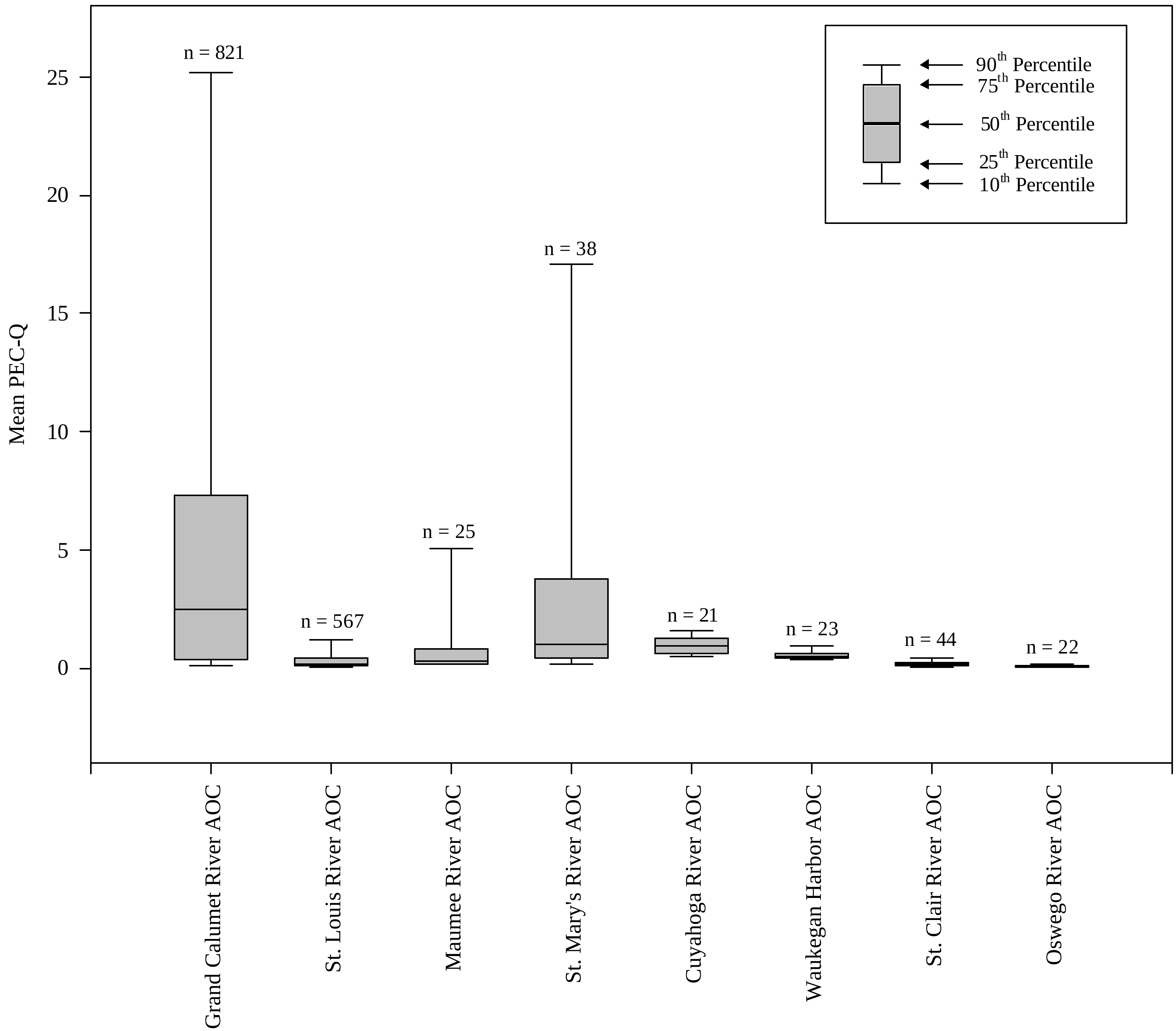

Figure 5. Cumulative distribution of mean PEC-Qs for surficial sediment samples collected in selected Great Lakes AOCs.

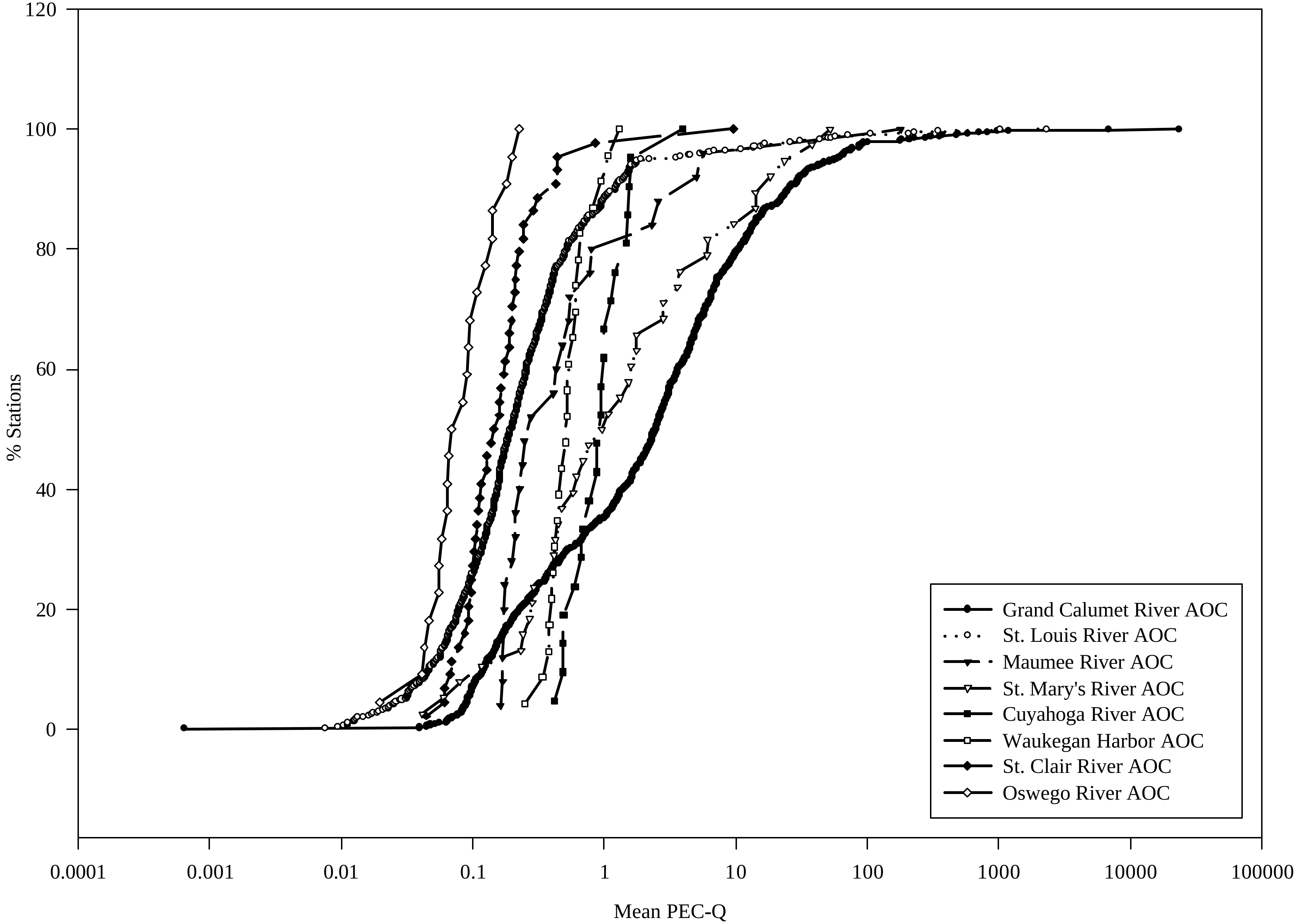

Figure 6. Box and whisker plot showing mean PEC-Q distribution for selected areas in North America.

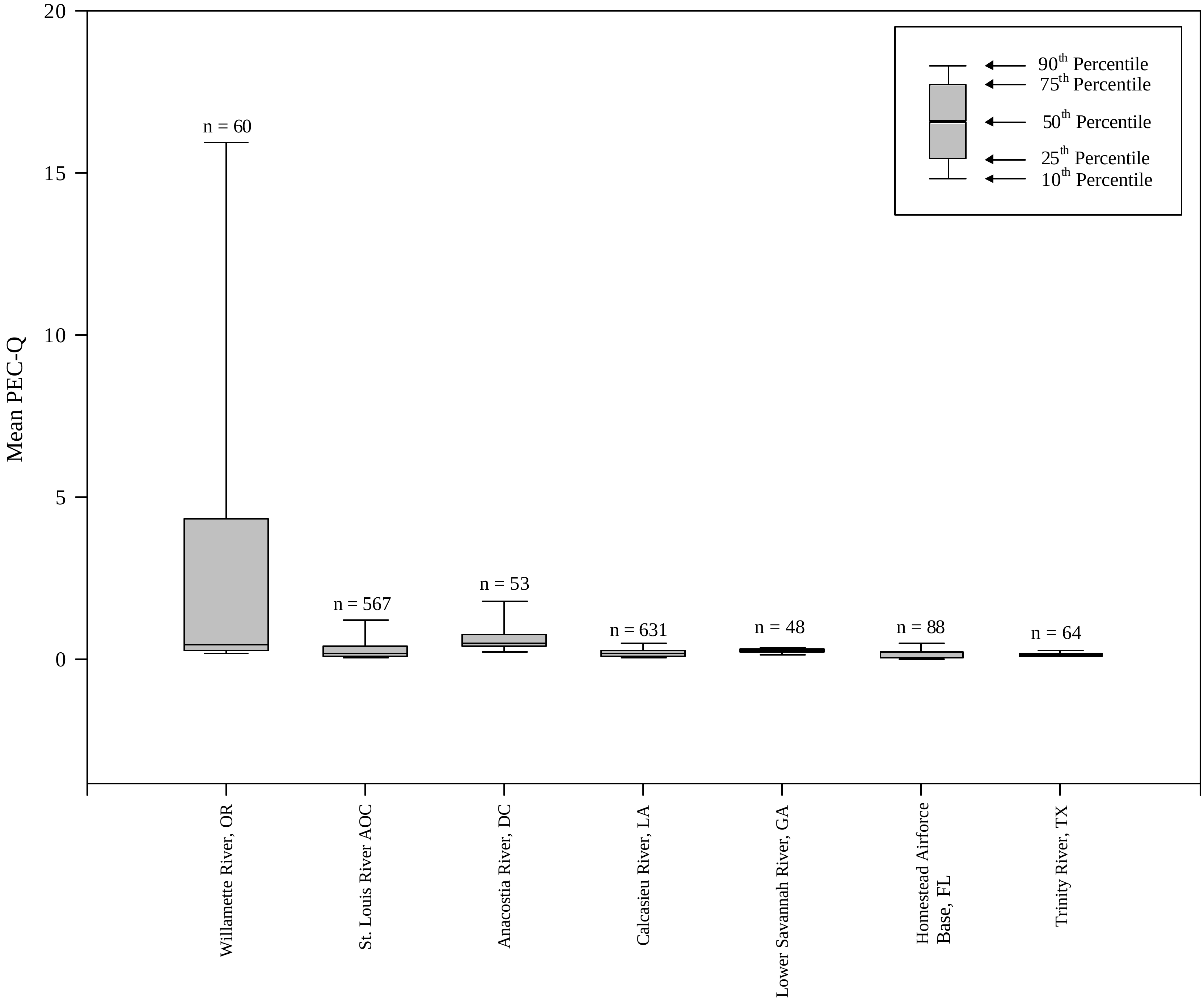

Figure 7. Cumulative distribution of mean PEC-Qs for sediment samples collected for selected areas elsewhere in North America.