AN EVALUATION OF SEDIMENT QUALITY CONDITIONS IN THE TRIBUTARIES OF PRESQUE ISLE BAY: 2001 - 2011

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January 2012 (Revised September 2012)

Acknowledgements

We would like to thank Dr. Rick Diz, Gannon University, for the use of his 2001 sediment chemistry data and the United States Environmental Protection Agency's Great Lakes Restoration Initiative Program for providing the funding necessary to undertake this sampling effort. In addition, we would like to thank Dr. Robert Light, Penn State Behrend; Eric Obert, Pennsylvania Sea Grant; and Karla Kaczmarek, Pennsylvania Sea Grant, for their critical review of this document.

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1.0 Abstract

In 1991, Presque Isle Bay became the Great Lakes 43rd and final Area of Concern, partially due to a restriction on dredging as a result of the presence of contaminated sediments. In 2007, the restrictions on the dredging beneficial-use impairment was delisted for Presque Isle Bay. As a result of the delisting, the *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan* was developed to ensure that the quality and quantity of water and sediment entering Presque Isle Bay from the watershed would not cause further adverse impacts to the bay's ecosystem. Measuring the success of restoration and protection efforts relies heavily upon a long-term watershed monitoring plan. The objective of this study was to evaluate the sediment quality conditions at 19 stream sites within the Presque Isle Bay watershed, in accordance with the monitoring recommendations of the plan. Chemicals of potential concern (COPC) were evaluated against existing sediment quality guidelines and the ecosystem health targets developed for Presque Isle Bay, including mean PEC-Q, SEM-AVS, SEM-AVS/f_{oc}, and ∑ESB-TUs. Results indicated that copper, lead, nickel, zinc, and oil and grease concentrations decreased at the majority of the sites assessed in 2011 compared to 2001; however, a few sites had increased metal concentrations when evaluated in 2011. The bioavailability of metals was assessed using SEM-AVS and SEM-AVS/f_{oc} measurements. The ecosystem health target for SEM-AVS is not being met as only 16% of the sites had a SEM-AVS less than zero. However, the ecosystem target for SEM-AVS/f_{oc} is being met as 100% of the sites had a SEM-AVS/f_{oc} less than 3,000 μmol g^{-1} OC. Sediment quality guidelines were exceeded at six sites. When potential toxicity was evaluated considering a mixture of contaminants (mean PEC-Q), the ecosystem health target for mean PEC-Q was met at 95% of the sites had a PEC-Q less than 1.0. The bioavailability of PAHs was assessed by calculating ∑ESB-TUs. The ecosystem target for ESB-TUs is not being met as only 68% of the sites had a ∑ESB-TU less than 1.0. The results of this study provide a robust dataset in which to compare future COPC sediment concentrations. Initial watershed restoration efforts should focus on sub-watersheds where COPC concentrations exceeded sediment quality guidelines, in addition to the subareas recommended in the plan.

2.0 Introduction

Presque Isle Bay is a 5.7-square-mile embayment located in northwestern Pennsylvania on the southern shore of Lake Erie. The bay's watershed drains a highly urbanized area (62.6% imperviousness) of approximately 26.22 square miles, including portions of Millcreek Township, City of Erie, Harborcreek Township, Summit Township, and Greene Township in Erie County, Pennsylvania. Tributaries of the bay include, from west to east, Scott Run, Cascade Creek, Mill Creek, and its tributary Garrison Run (**Map 1**). These tributaries comprise 88.3% of the bay's watershed; the remainder of the watershed (11.7%) is comprised of small unnamed tributaries and direct runoff to the bay.

Like so many Great Lakes communities, Erie's history and bayfront are characterized by industrial and wastewater problems; however, in the 1980s, the city's bayfront began to transition from an industrial-dominated zone to one of tourism and recreation (Diz 2005). As industry began to fade from the Erie area in the early 1980s, environmentally minded citizens banded together with the common goal of restoring and protecting Presque Isle Bay. In 1991, their efforts ultimately lead to Presque Isle Bay being listed as the 43rd and final Area of Concern (AOC) under the Great Lakes Water Quality Agreement (GLWQA). In 2005, a comprehensive sediment evaluation of Presque Isle Bay did not reveal evidence of "chemical hotspots" and found that the sediment was not toxic to aquatic life, sediment being deposited was "cleaner" than older sediment, and ecosystem health targets were being met (Boughton 2006). As a result, in July 2007, the U.S. Environmental Protection Agency approved the petition to delist the restrictions on dredging BUI.

As a result of the delisting, the *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan* (referred to as the plan) was developed to provide a framework for action that would ensure that the quality and quantity of water and sediment entering Presque Isle Bay would not cause adverse impacts to the bay's ecosystem (Rafferty *et al.* 2010). The plan summarizes a comprehensive GIS-based data collection, assessment, and analysis effort; and serves as a living document that provides a model to drive coordinated restoration, protection, and monitoring projects within the watershed. Measuring the success of watershed restoration and protection efforts relies heavily upon a long-term watershed monitoring plan. Diz and Johnson (2002), Campbell *et al.* (2002), and Pyron *et al.* (2004) provided a baseline chemical, physical, and biological assessment of the Presque Isle Bay watershed by assessing a total of 16 sites along Scott Run, Cascade Creek, Mill Creek, and Garrison Run. The long-term monitoring plan calls for the 16 sites to be re-assessed every five years, beginning in 2011.

The objective of this study was to evaluate the sediment quality conditions at the 16 sites assessed by Diz and Johnson (2002), per the monitoring recommendations of the plan. Results of the sediment quality conditions were compared to those observed by Diz and Johnson (2002) and Rafferty (2010), and evaluated against the ecosystem health targets set for Presque Isle Bay (Boughton 2006).

3.0 Methods

3.1 Sampling Sites and Sample Collection

In May 2011, surficial sediment samples were collected from 19 sites along the tributaries of Presque Isle Bay (**Table 1**; **Map 2**). Of the 19 sites, 16 sites were previously sampled by Diz and Johnson (2002) in 2001 and four sites were previously sampled by Rafferty (2010) in 2009. Due to access restrictions, sediment samples from near the mouth of Mill Creek (MC 0) were collected by lowering a Petite Ponar dredge to the streambed until the sampler was triggered. Once triggered, the sampler was gently retrieved and placed upright in a stainless steel pan onshore. The entire sediment sample was transferred to a labeled (site location and date) 7.0-quart plastic container. Two samples were collected and homogenized using a stainless steel spoon. Sediment samples from all other locations were collected by scooping the upper 1.0 cm of sediment from the streambed using a stainless steel spoon and transferred to a labeled 7.0-quart plastic container. Sediment was collected across the cross section of the stream. Prior to sampling at the next location, all sampling equipment was decontaminated by rinsing with site water; scrubbing the equipment with Alconox® and rinsing with site water; rinsing with Acetone; and rinsing with de-ionized water. All stream samples were stored in 48-L coolers with Blue Ice® and transferred to the Tom Ridge Environmental Center for processing.

3.2 Sample Processing

All samples were processed at the Tom Ridge Environmental Center. Prior to processing, each sample was logged on a chain of custody form provided by Test America, Inc. Sediment samples were transferred from the 7.0-quart plastic containers to the properly labeled (site, date, and analysis) glass amber container for analysis. Glass amber containers for each sample included: 1 - 4 oz (AVS/SEM); 1 – 4 oz (TKN/P); 1 – 8 oz (TOC, oil and grease, metals, nitrite, and nitrate); 1 – 8 oz (pesticides, PCBs, SVOCs, TS); and 1 – 32 oz (grain size and PAHs). The glass amber jars were filled with no headspace and the lids were sealed with duct tape prior to shipping. The samples were wrapped in bubble wrap and packed in 48.0-liter coolers with Blue Ice® and the chain of custody forms. The coolers were sealed with duct tape and shipped overnight to Test America, Inc. in Pittsburgh, Pennsylvania. Prior to processing each sample, all sampling equipment was decontaminated by: rinsing with water; scrubbing the equipment with Alconox® and rinsing with site water; rinsing with Acetone; and rinsing with de-ionized water. All remaining sediment was archived at the Tom Ridge Environmental Center following processing.

3.3 *Sample Analysis*

All 2011 and 2009 sediment samples were analyzed for: acid volatile sulfides (AVS) and simultaneously extracted metals (SEM) ratio; total kjeldahl nitrogen; phosphorus, total organic carbon (TOC); oil and grease; metals; nitrite and nitrate; pesticides; polychlorinated biphenyls (PCBs); semi-volatile organic carbons (SVOCs – nitrosamines); total solids (TS); grain size; and polycyclic aromatic hydrocarbons (PAHS) (**Table 2**). All 2011 and 2009 sample analysis was performed by Test America, Inc. All 2001 sediment samples were analyzed for cadmium, copper, lead, nickel, zinc, and oil and grease by Diz and Johnson (2002).

3.4 *Historical Data and Sediment Quality Guidelines*

Heavy metal (cadmium, copper, lead, nickel, and zinc) and oil and grease data were compared to data reported by Diz and Johnson (2002) and Rafferty (2010). Concentrations of each analyte were compared between years to determine if there was a change in concentration.

Data were compared against numerical sediment quality guidelines (SQG) (MacDonald *et al.* 2000) and assessed for Presque Isle Bay by Boughton (2006). Numerical SQGs assist with identifying chemicals of potential concern (COPCs) and represent a useful tool for assessing the quality of freshwater sediments. Numerical SQGs used in this study, include severe effect level (SEL), probable effect concentration (PEC), heavily polluted threshold (HPT), and probable effect level (PEL).

3.5 *Assessing Ecosystem Health Targets*

The ecosystem health target is met if at least 90% of the sediment samples have the conditions necessary to support healthy benthic invertebrate communities, as indicated by:

- a mean PEC-Q less than 1.0;
- the molar concentration of simultaneously extracted divalent metals is less than the molar concentration of acid volatile sulfide (SEM-AVS < 0.0);
- SEM-AVS/f_{oc} is less than 3,000 µmol g^{-1} OC;
- ∑ESB-TUs less than 1.0 (Boughton 2006).

The mean PEC-Qs were calculated for each sample by dividing the concentration of a chemical by its PEC; adding those quotients for metals, PAHs, and PCBs; and dividing by three. The SEM-AVS ratio was calculated by subtracting the AVS value from the SEM value. The SEM-AVS ratio was adjusted for organic carbon by dividing the difference between the SEM and AVS values by the fraction of organic carbon of the sample (f_{oc}). The ESB-TU for an individual PAH was calculated by dividing the PAH concentration by the fraction of organic carbon (f_{oc}) (and dividing by 1,000 to account for differences in units), which results in the organic carbon normalized PAH concentration ($C_{oc, PAHi}$) (reviewed by Burgess 2009). The $C_{oc, PAHi}$ was then divided by an organic carbon normalized toxicity value ($C_{oc, PAHi,FCVi}$), resulting in an ESB-TU for the PAH (values are provided in USEPA 2003). The individual ESB-TUs for the 34 PAHs assessed were summed, resulting in a ∑ESB-TU for each site.

4.0 Results

4.1 *Historical Data and Sediment Quality Guidelines (SQG)*

Concentrations of cadmium, copper, lead, nickel, zinc, and oil and grease varied across sites and years (**Table 3**). The number of samples that contained individual COPCs at concentrations greater than the selected SQGs (**Table 4**) varied among the contaminants measured in 2011 (**Table 5**), 2009 (**Table 6**), and 2001 (**Table 7**).

Cadmium concentrations measured in 2011 were higher than concentrations observed in 2001 at 13 of the 16 sites sampled in both years, and cadmium concentrations measured in 2011 were lower than concentrations observed in 2009 at three of the four sites sampled in both years (**Figure 1**). While cadmium concentrations measured in 2011 exceeded concentrations observed in 2001 at many of the sites, none of the sites sampled in 2011 had cadmium concentrations exceed the PEC (4.98 mg kg^{-1}); however, the PEC for cadmium was exceeded at site GR 1 in 2001.

Copper concentrations measured in 2011 were lower than concentrations observed in 2001 at 14 of the 16 sites sampled in both years, and copper concentrations measured in 2011 were lower than concentrations observed in 2009 at all four sites sampled in both years (**Figure 2**). The copper concentrations observed at sites CC 3 (713 mg kg^{-1}) and CC 6 (1580 mg kg^{-1}) in 2011 were substantially higher than concentrations observed in 2001 (65.6 mg kg^{-1} and 84.8 mg kg^{-1}, respectively). The PEC (149 mg kg^{-1}) was exceeded at sites CC 3 and CC 6 in 2011; however, the PEC was not exceeded at any of the sites in 2001.

Lead concentrations measured in 2011 were lower than concentrations observed in 2001 at 14 of the 16 sites sampled in both years, and lead concentrations measured in 2011 were lower than concentrations observed in 2009 at all four sites sampled in both years (**Figure 3**). While lead concentrations measured in 2011 did exceed concentrations observed in 2001 at two sites, none of the sites sampled in 2011 had lead concentrations exceed the PEC (128 mg kg^{-1}). The PEC for lead was exceeded at sites CC 5 and GR 1 in 2001.

Nickel concentrations measured in 2011 were lower than concentrations observed in 2001 at all 16 sites sampled in both years, and nickel concentrations measured in 2011 were lower than concentrations observed in 2009 at all four sites sampled in both years (**Figure 4**). Nickel concentrations exceeded the PEC (48.6 mg kg^{-1}) at site CC 6 in 2011; however, the PEC was exceeded at seven sites in 2001, including sites SR 1, CC 1, CC 2, CC 3, CC 5, CC 6, and GR 1.

Zinc concentrations measured in 2011 were lower than concentrations observed in 2001 at all 16 sites sampled in both years, and zinc concentrations measured in 2011 were lower than concentrations observed in 2009 at three of four sites sampled in both years (**Figure 5**). Zinc concentrations did not exceed the PEC (459 mg kg^{-1}) at the sites sampled in 2011, 2009, or 2001.

Oil and Grease concentrations measured in 2011 were substantially lower than concentrations observed in 2001 at all 16 sites sampled in both years; however, oil and grease concentrations measured in 2011 were slightly higher than concentrations observed in 2009 at two of the four sites sampled in both years (**Figure 6**). Oil and Grease concentrations exceeded the SEL (2,000 mg kg^{-1}) at site GR 0 in 2011 and GR 1 in 2011 and 2009; however, the SEL was exceeded at all 16 sites sampled in 2001.

In 2011, barium concentrations exceeded the HPT (60 mg kg^{-1}) at sites CC 3, CC 6, MC 7, and GR 0 and in 2009, the PEC was exceeded at site GR 0 (**Figure 7**). In 2011, acenaphthene concentrations exceeded the PEL (88.9 µg kg^{-1}) at sites CC 3, CC 5, and MC 7 and in 2009, the PEL was exceeded at site MC 0 (**Figure 8**). In 2011, benz(a)anthracene, benzo(a)pyrene, and chrysene concentrations exceeded the PEC (1,050; 1,450; and 1,290 µg kg^{-1} respectively) at site MC 7 and in 2009, the PEC's were exceeded at site MC 0 (**Figure 9**; **Figure 10**; and **Figure 11**). In 2011, fluoranthene and dibenz(a,h)anthracene concentrations exceeded the PEL and PEC (135 and 2,230 µg kg^{-1} respectively) at sites CC 3 and MC 7 and in 2009, the PEL and PEC were exceeded at sites CC 1, MC 0, and GR 0 (**Figure 12**; **Figure 13**). In 2011, phenanthrene and pyrene concentrations exceeded the PEC (1,170 and 1,520 µg kg^{-1}) at sites CC 3, CC 5, MC 7, and GR 1 and in 2009, the PEC for phenanthrene was exceeded at sites CC 1 and MC 0 and the PEC for pyrene was exceeded at sites CC 1, MC 0, and GR 0 (**Figures 14**; **Figure 15**). In 2011, the concentration of total PAHs did not exceeded the PEC at any site and in 2009, the PEC was exceeded at site MC 0 (**Figure 16**). In 2011, the concentration of total PCBs exceeded the PEC (676 µg kg^{-1}) at site GR 0 (**Figure 17**). In 2011, the concentration of total kjeldahl nitrogen exceeded the heavily polluted threshold (2,000 mg kg^{-1}) at sites MC 7 and GR 1 and in 2009, the moderately polluted threshold (1,000 mg kg^{-1}) was exceed at site MC 0 (**Figure 18**). In 2011, the concentration of total phosphorus exceeded the moderately polluted threshold (420 mg kg-1) at site MC 7 and in 2009, the moderately polluted threshold was exceeded at sites SR 0 and MC 0 (**Figure 19**). Organochlorine pesticide concentrations did not exceed PECs at any of the sites assessed in 2011 and 2009. All 2011 chemical data are presented in **Appendix D**.

4.2 Ecosystem Health Targets

4.2.1 Mean Probable Effects Concentration Quotient (PEC-Q)

The mean PEC-Q is a better indicator of potential toxicity, as it considers the effect of contaminant mixtures in the sediment. Consistent with the ecosystem health targets, individual sediment samples were designated as having COPC concentrations sufficient to result in significantly reduced survival or growth of freshwater amphipods if the mean PEC-Q was greater than 1.0. In 2011, the mean PEC-Q exceeded 1.0 at site GR 0 and in 2009, the PEC-Q did not exceed 1.0 at any of the sites (**Table 8**; **Figure 20**).

4.2.2 Simultaneously Extracted Metals-Acid Volatile Sulfides (SEM-AVS)

Bioavailability measures the extent to which contaminants are available for uptake by benthic organisms. The bioavailability of metals was assessed using SEM-AVS and SEM-AVS/f_{oc} measurements. Metals present in the sediment are considered to be potentially bioavailable when SEM-AVS is greater than zero and/or when SEM-AVS/f_{oc} is greater than 3,000 µmol g^{-1} OC. In 2011, the SEM-AVS exceeded zero at 16 of the 19 sites sampled and in 2009, the SEM-AVS exceeded zero at all four sites sampled (**Table 9**; **Figure 21**). In 2011 and 2009, the SEM-AVS/f_{oc} did not exceed 3,000 µmol g^{-1} OC at any of the sites sampled (**Figure 22**).

4.2.3 Equilibrium Sediment Benchmark Toxicity Units (ESB-TU)

The bioavailability of PAHs was assessed by calculating ∑ESB-TUs. PAHs present in the sediment are considered to be potentially bioavailable when the ∑ESB-TU is greater than 1.0. In 2011, six of the 19 sites had a calculated ∑ESB-TU greater than 1.0 and in 2009, all four sites assessed had a calculated ∑ESB-TU greater than 1.0 (**Table 10**; **Figure 23**). The ∑ESB-TUs were lower in 2011 at the four sites assessed in both 2011 and 2009, and three of the four sites assessed in 2011 had a calculated ∑ESB-TU less than 1.0.

5.0 Discussion

The *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan* established a long-term monitoring plan for the Bay's watershed, including the evaluation of sediment chemistry throughout the watershed. The results of this study represent a follow up to Diz and Johnson (2002) and Rafferty (2012), and will be used as baseline concentrations in evaluating the success of watershed restoration and protection efforts in the future.

Copper, lead, nickel, zinc, and oil and grease concentrations decreased at the majority of the sites assessed in 2011 compared to 2001; however, a few sites had increased metal concentrations when evaluated in 2011. Of particular concern, are the copper concentrations observed at sites CC 3 and CC 6 in

2011. Concentrations at these sites were well above the PEC (149 mg kg^{-1}). Site CC 6 is located immediately downstream from the former Currie Landfill, which is currently being remediated under the Pennsylvania Department of Environmental Protection's Hazardous Sites Cleanup Program in accordance with Hazardous Sites Cleanup Act (HSCA) (35 P. S. §§ 6020.101—6020.1305). In addition, there is a metal processing facility located near site CC 6; however, the metal facility is located within the Scott Run watershed. Site CC 3 is located downstream of a heavily industrialized area. Despite, the elevations in some chemical concentrations in 2011 compared to 2001, the number of sites with concentrations that exceeded PECs decreased from 2001 to 2011. Cadmium exceeded the PEC at site one site in 2001 and none of the sites in 2011. Lead exceeded the PEC at one site in 2001 and none of the sites in 2011. Nickel exceeded the PEC at seven sites in 2001 and one site in 2011. Oil and grease exceeded the PEC at all 16 sites in 2001 and one site in 2011.

Better measures of potential metal toxicity are SEM-AVS and SEM-AVS/f_{oc}. Both measures assess the bioavailability of cadmium, nickel, lead, copper, and zinc. SEM-AVS measurements were not conducted by Diz and Johnson (2002). The SEM-AVS exceeded zero at 16 of the 19 sites assessed in 2011, which suggests that metal concentrations may be present in a soluble form and readily bioavailable to sediment-dwelling organisms at the 16 sites. The SEM-AVS ecosystem health target is not being met as only 16% of the sites had a SEM-AVS less than zero. However, when the SEM-AVS was normalized for organic carbon (SEM-AVS/f_{oc}) none of the sites exceeded the threshold, indicating that the metals should not be expected to be toxic to sediment-dwelling organisms as a result of being bound by the organic carbon. The ecosystem target for SEM-AVS/f_{oc} is met at 100% of the sites assessed in 2011 had a SEM-AVS/f_{oc} less than 3,000 µmol g^{-1} OC.

Additional COPCS were measured in 2011 and compared against sediment quality guidelines. Sediment quality guidelines were exceeded at a few of the sites, most notably at site MC 7 where 12 of the COPCs exceeded sediment quality guidelines. However, when potential toxicity was evaluated considering a mixture of contaminants (mean PEC-Q), the concentration of COPCs in the stream sediments is not expected to result in a high frequency of toxicity to benthic organisms. The ecosystem health target for PEC-Q is being met as 95% of the sites assessed in 2011 had a PEC-Q less than 1.0.

Last, the bioavailability of PAHs was assessed by calculating ∑ESB-TUs. The ∑ESB-TU was greater than 1.0 at six of the 19 sites assessed in 2011, suggesting that PAHs may be bioavailable to benthic organisms at these sites and could contribute to sediment toxicity. The ecosystem target is not being met as only 68% of the sites assessed in 2011 had an ∑ESB-TU less than 1.0.

It is concerning that sediment quality guidelines were exceeded at six of the 19 sites assessed in 2011 and two of the four ecosystem targets are not being met in the watershed, including SEM-AVS and ∑ESB-TU. Presque Isle Bay was delisted on the premise that ecosystem health targets were being met within the bay and that the watershed would not lead to future impairment of the bay. The exceedances of sediment quality guidelines and failure to comply with ecosystem health targets suggest that contaminated sediments from the watershed could lead to future impairments to Presque Isle Bay. However, sediment quality in the Presque Isle Bay watershed should improve as more restoration and protection projects focused on reducing stormwater input to Scott Run, Cascade Creek, Mill Creek, and Garrison Run are implemented. The results of this study provide a robust dataset in which to compare future COPC concentrations. Initial restoration efforts should be focused on stream locations (CC 3, CC 5, CC 6, MC 7, GR 0, and GR 1) where COPC concentrations exceeded sediment quality guidelines, in addition to the subareas recommended in the *Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan*.

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Appendix A: Figures

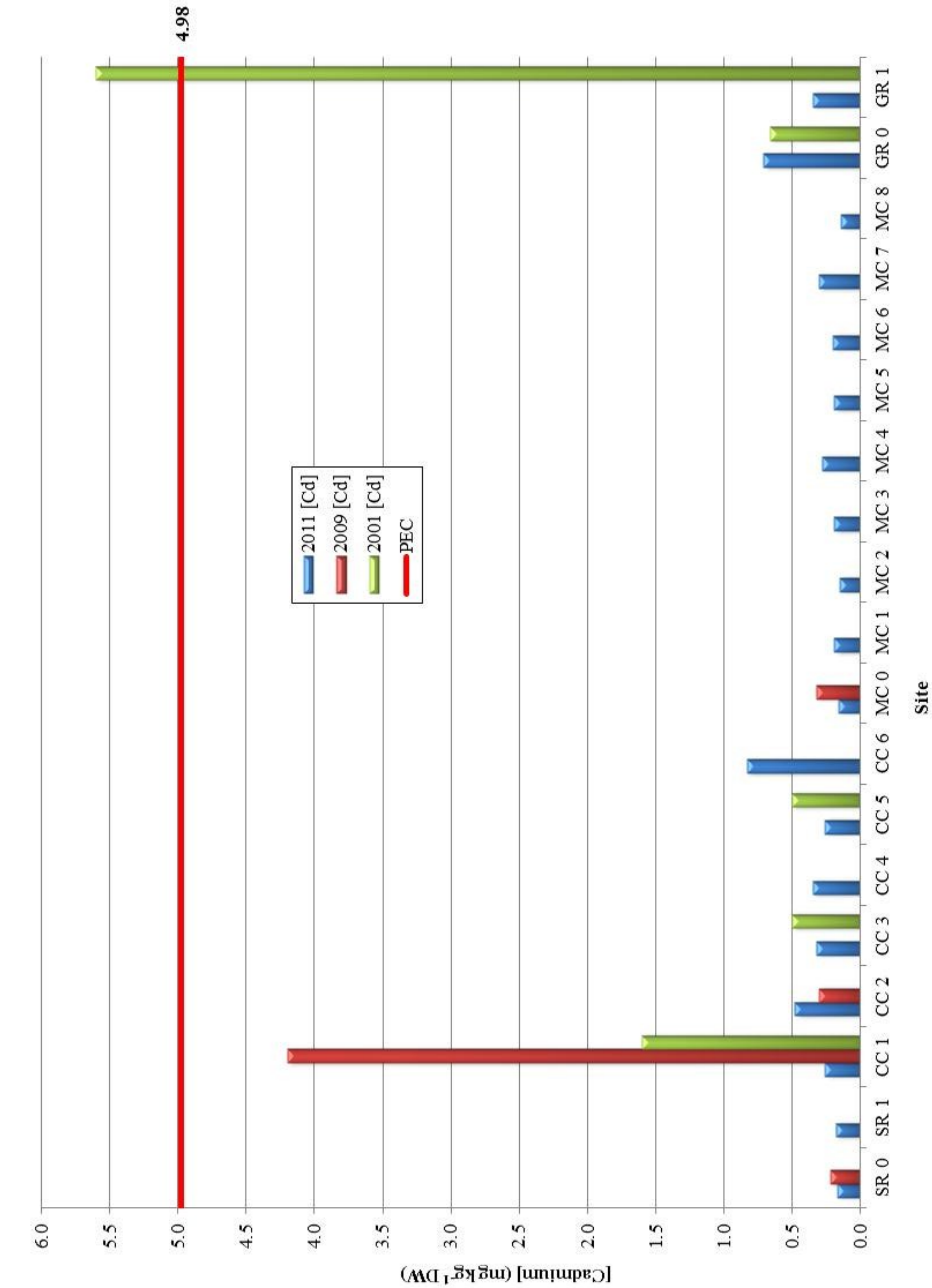

Figure 1. Cadmium concentrations in the Presque Isle Bay watershed: 2001—2011

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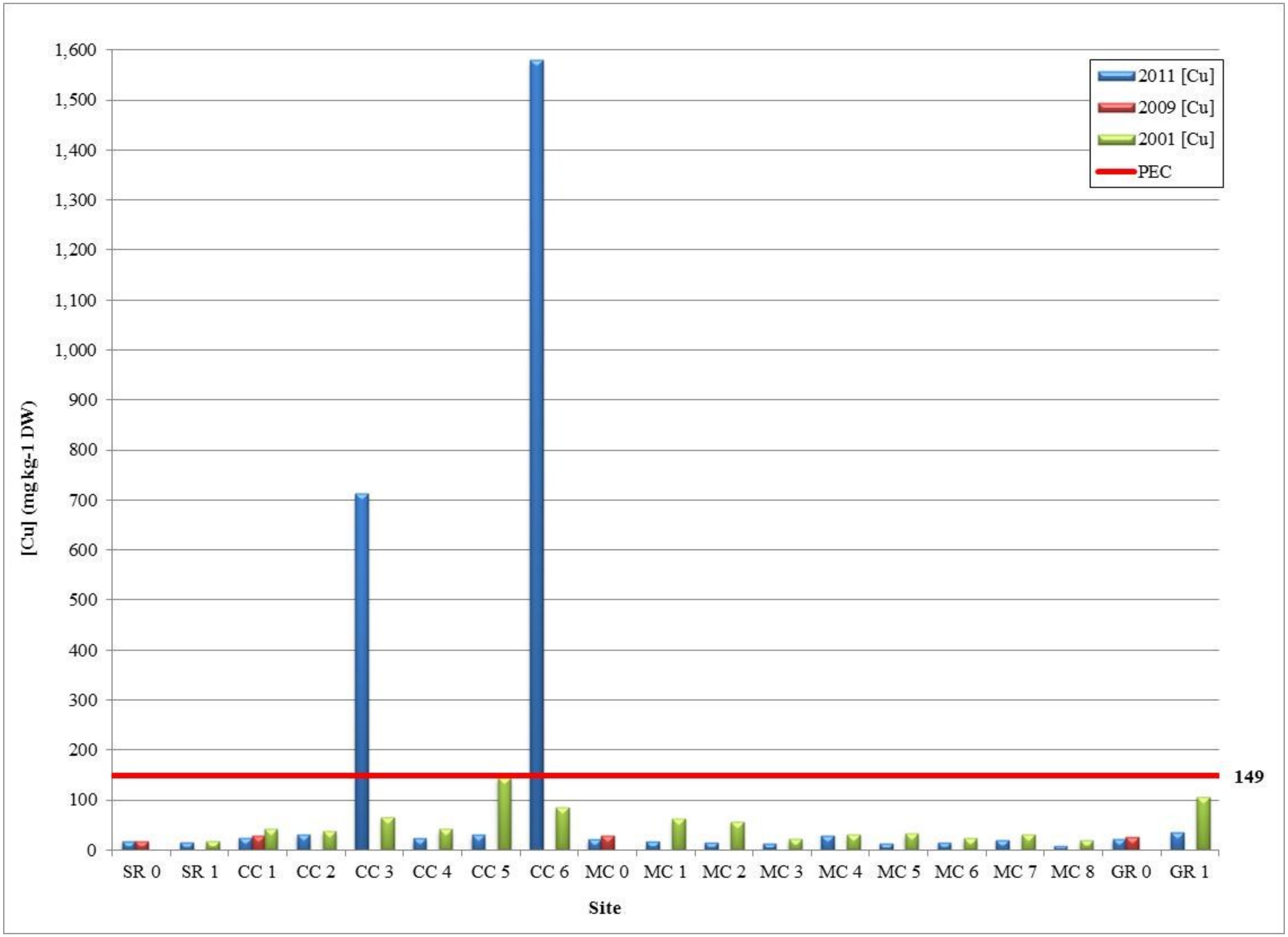

Figure 2. Copper concentrations in the Presque Isle Bay watershed: 2001—2011

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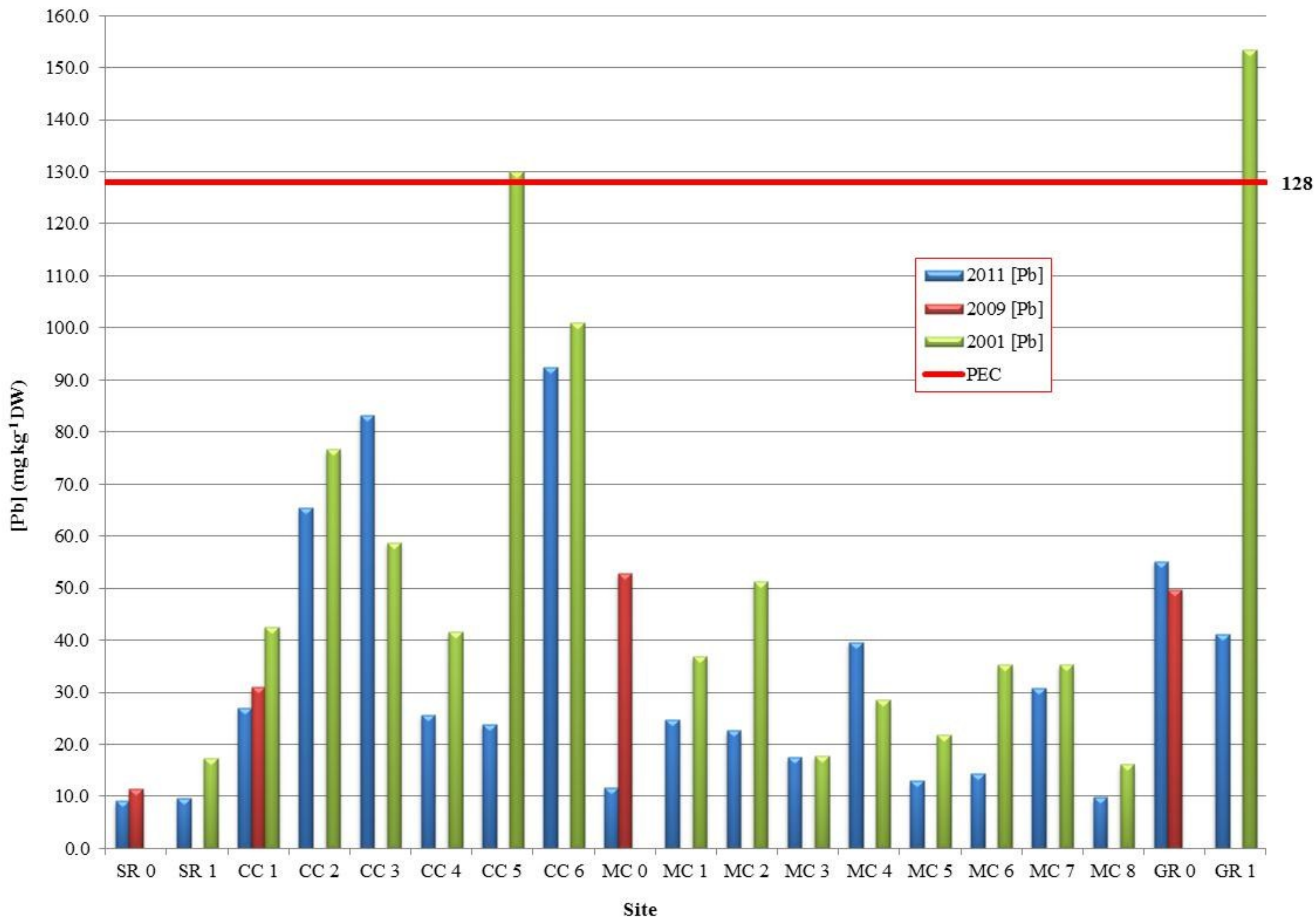

Figure 3. Lead concentrations in the Presque Isle Bay watershed: 2001—2011

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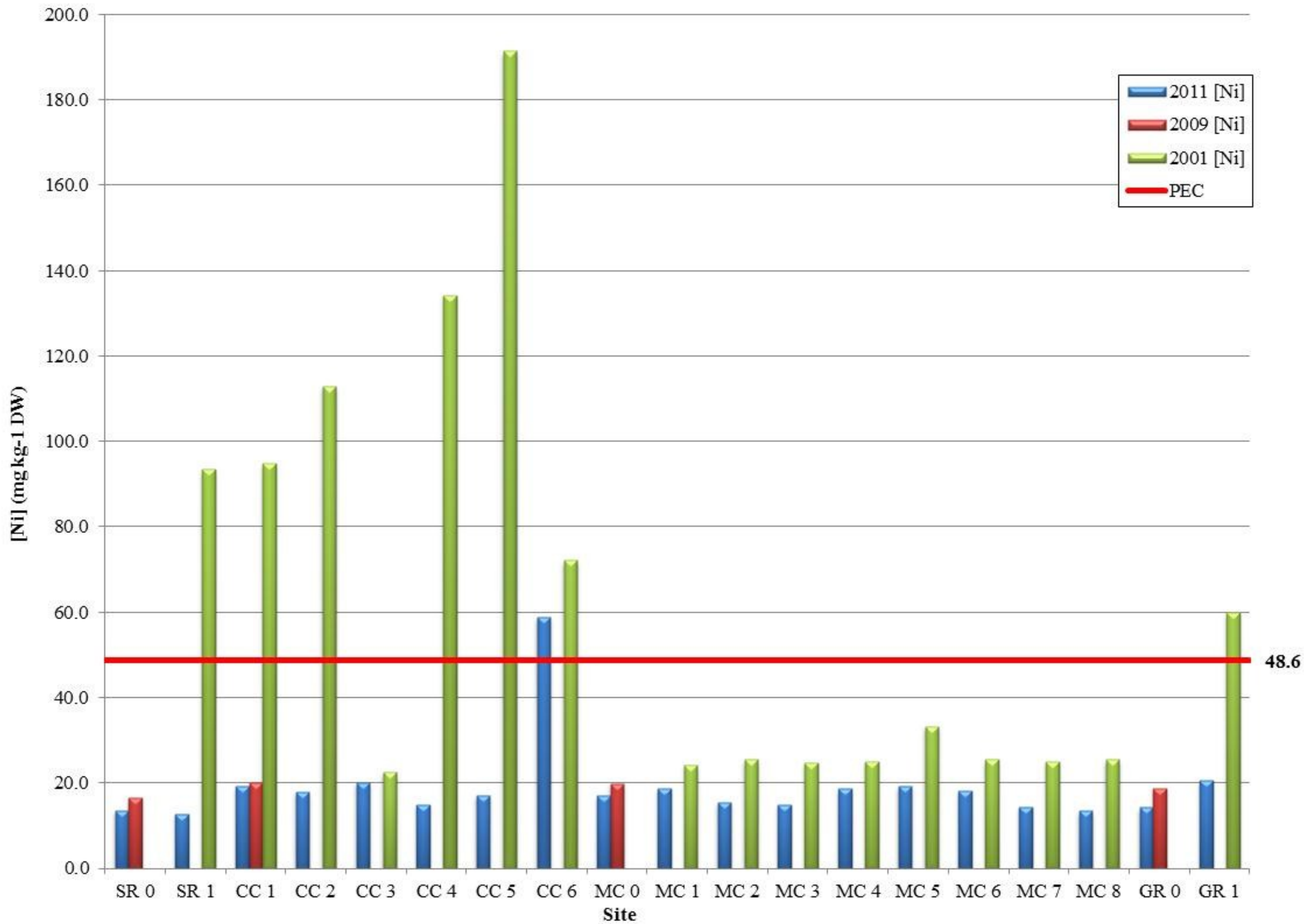

Figure 4. Nickel concentrations in the Presque Isle Bay watershed: 2001—2011

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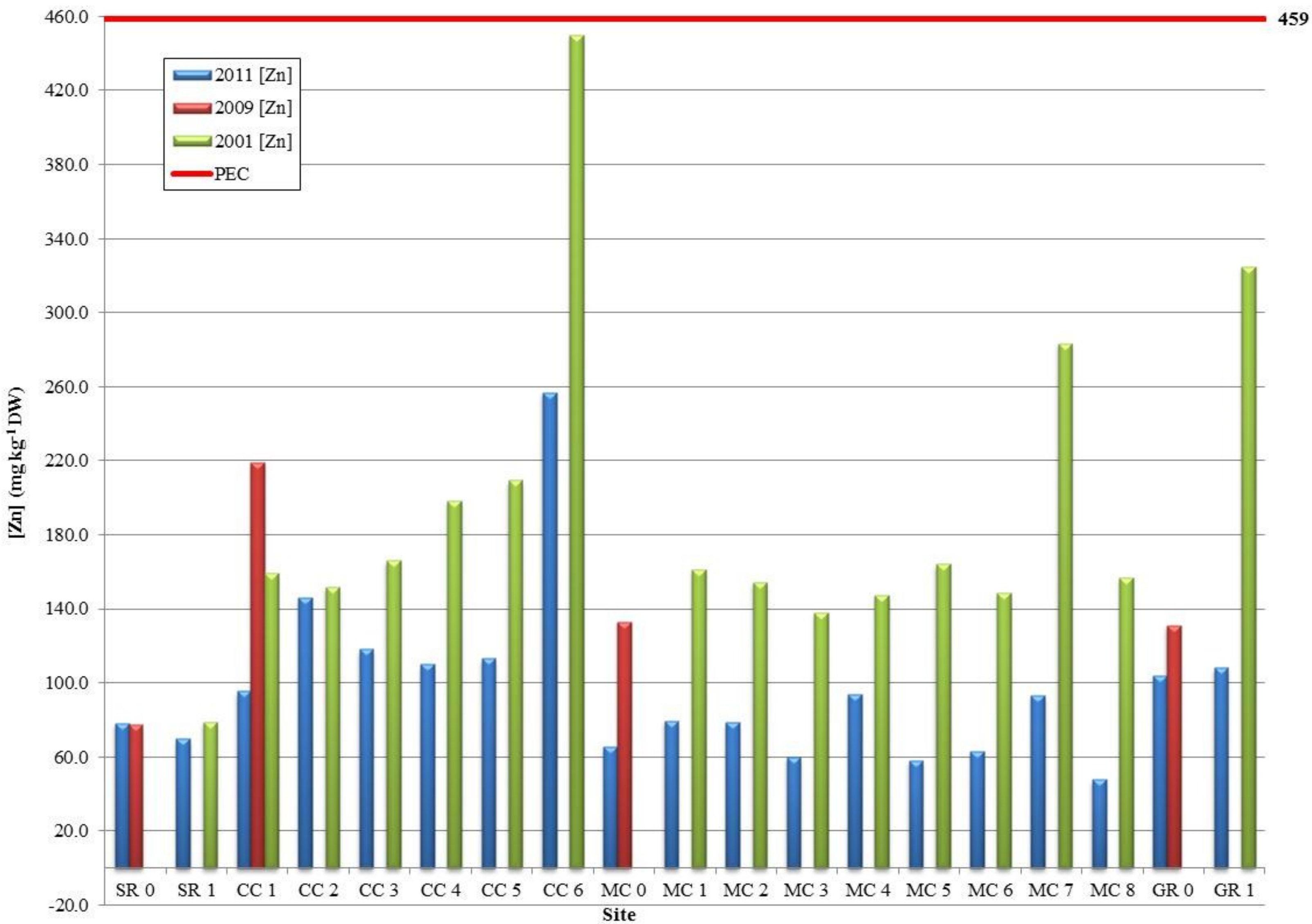

Figure 5. Zinc concentrations in the Presque Isle Bay watershed: 2001—2011

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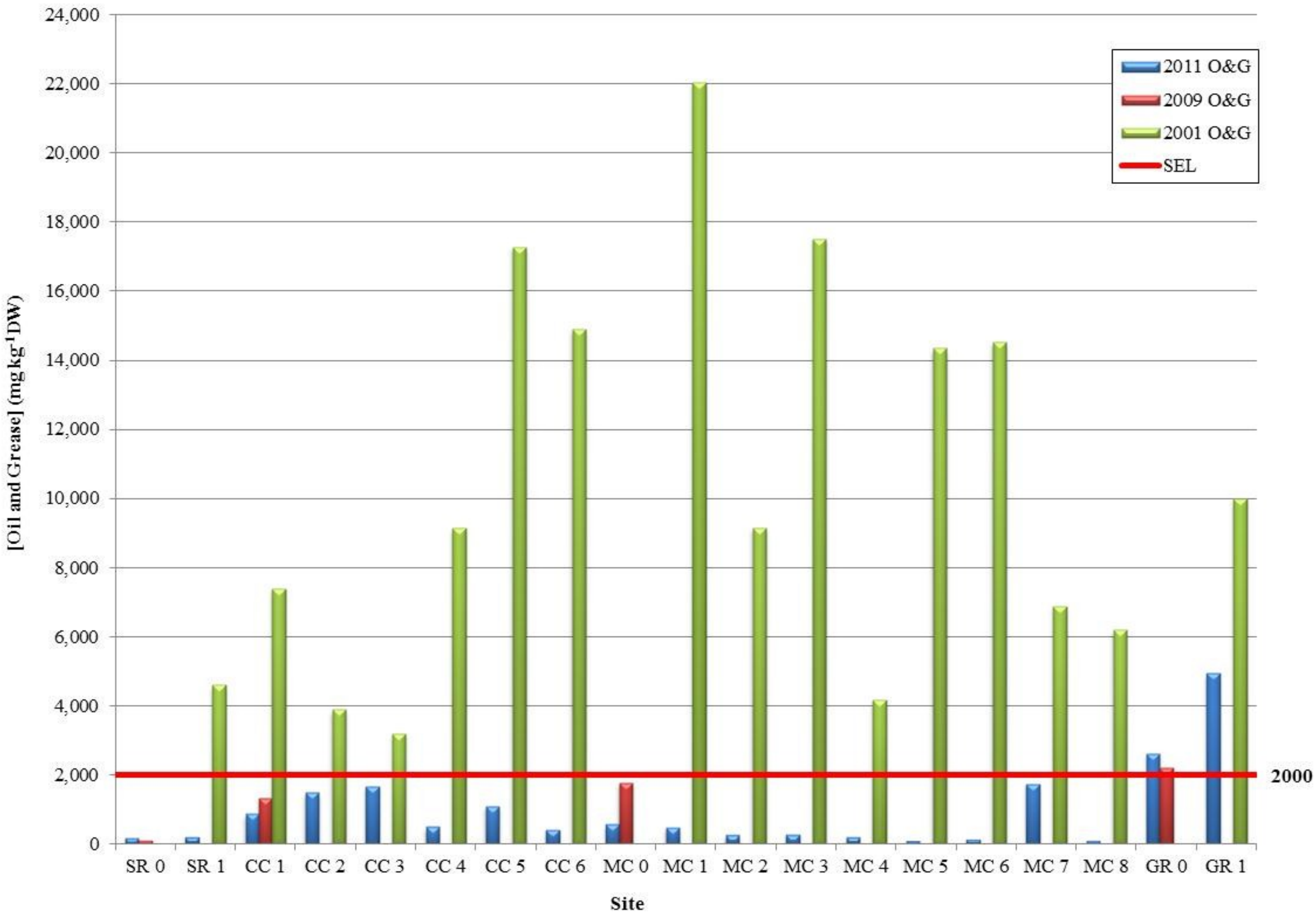

Figure 6. Oil and Grease concentrations in the Presque Isle Bay watershed: 2001—2011

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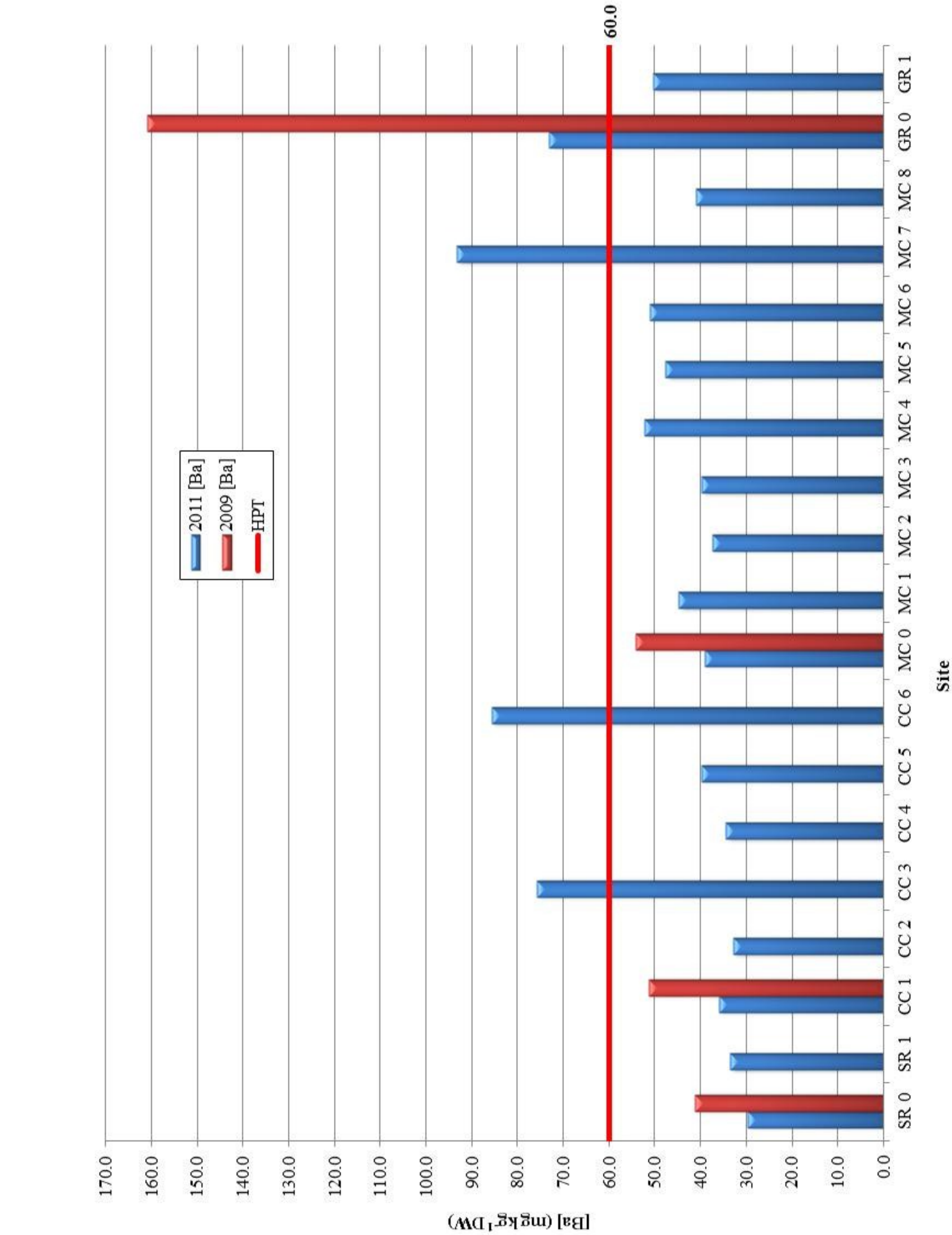

Figure 7. Barium concentrations in the Presque Isle Bay watershed: 2009—2011

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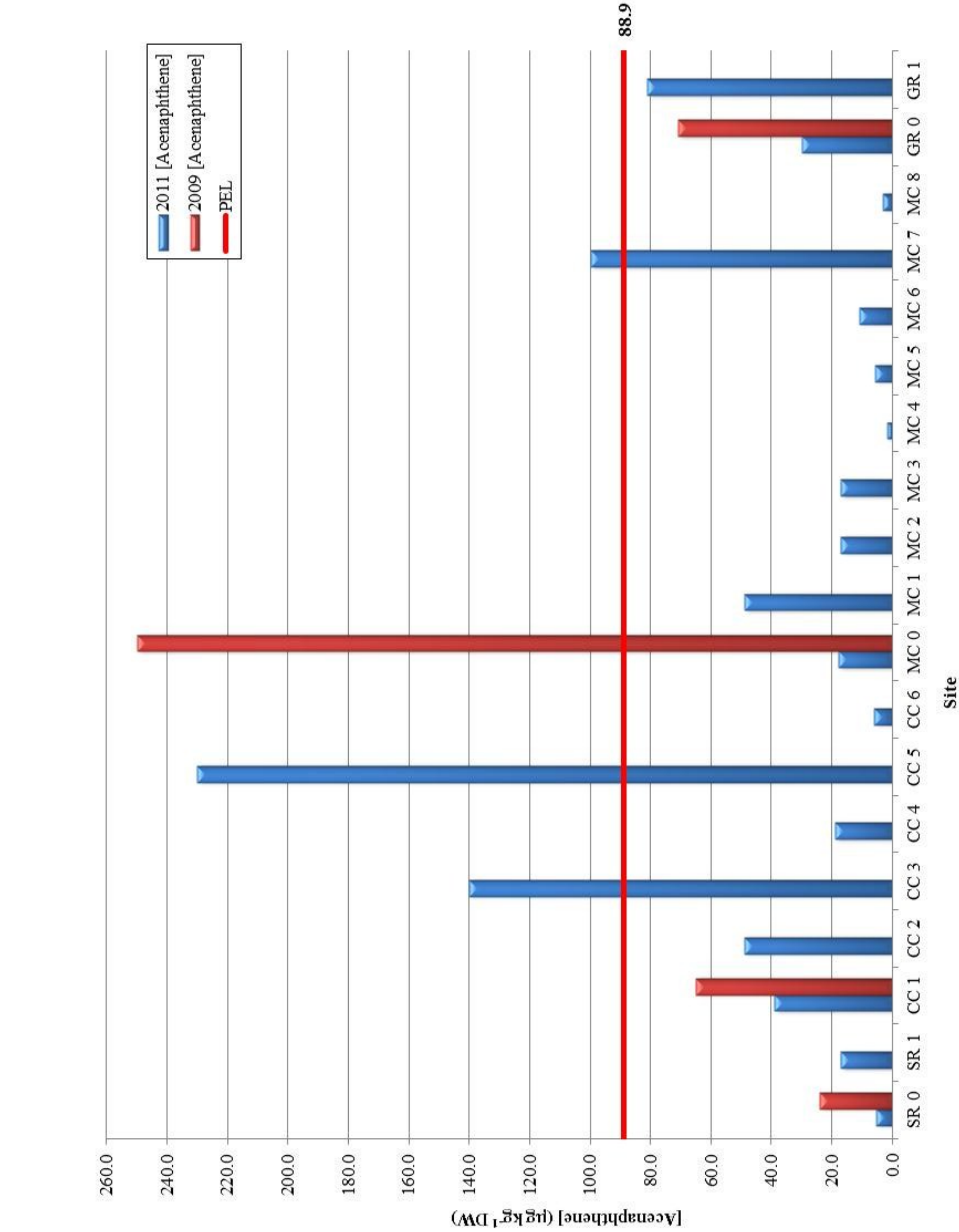

Figure 8. Acenaphthene concentrations in the Presque Isle Bay watershed: 2009—2011

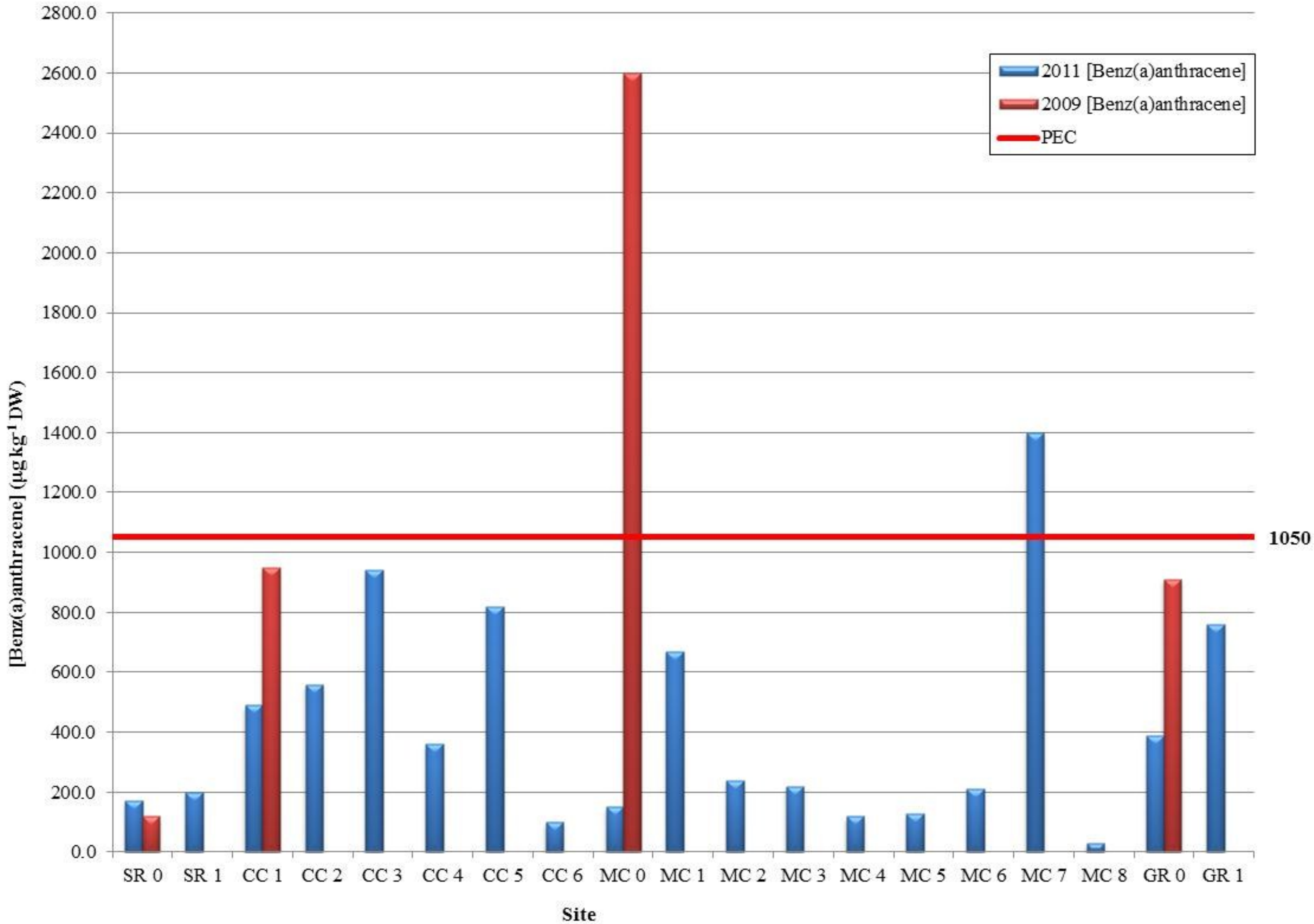

Figure 9. Benz(a)anthracene concentrations in the Presque Isle Bay watershed: 2009—2011

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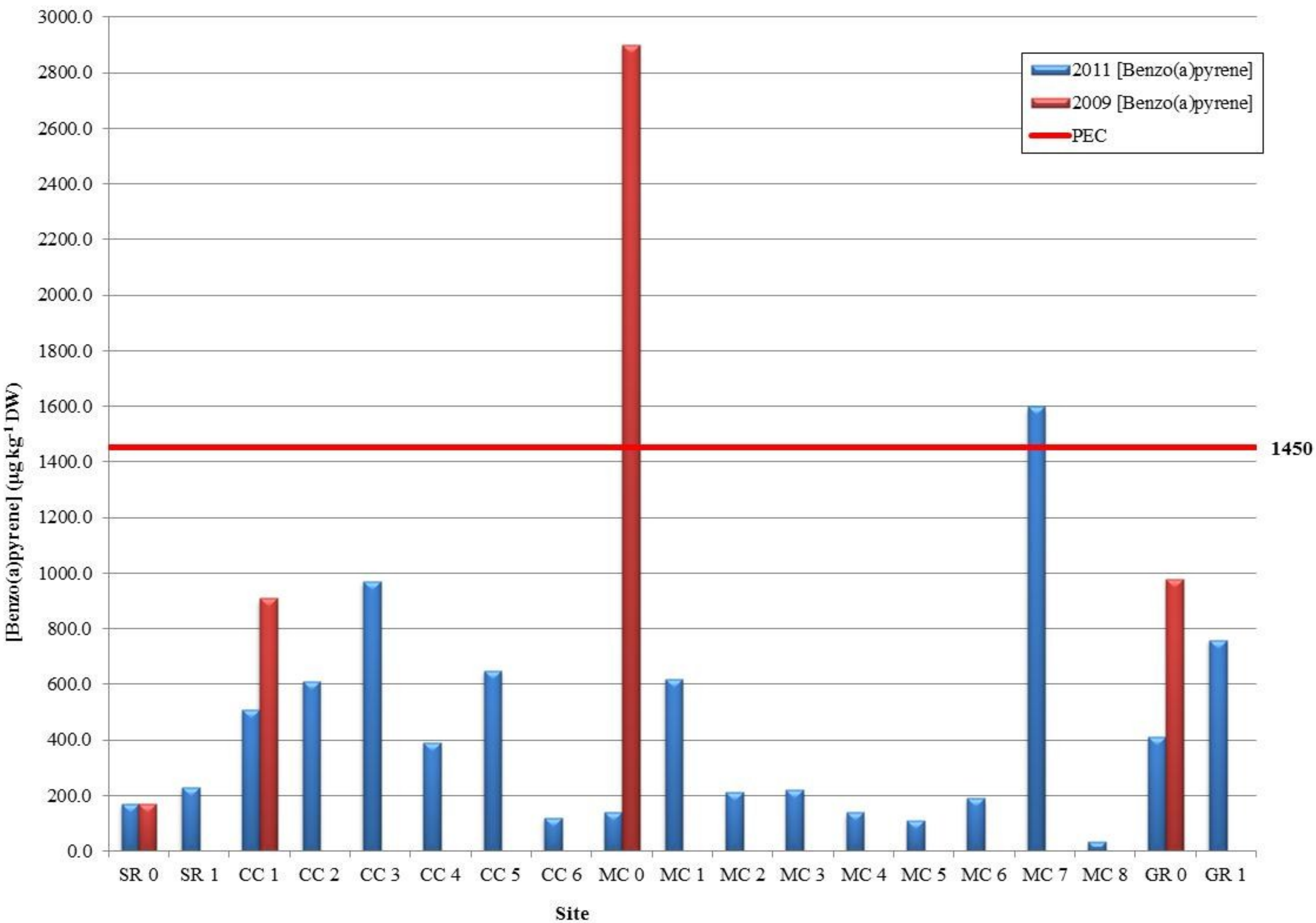

Figure 10. Benzo(a)pyrene concentrations in the Presque Isle Bay watershed: 2009—2011

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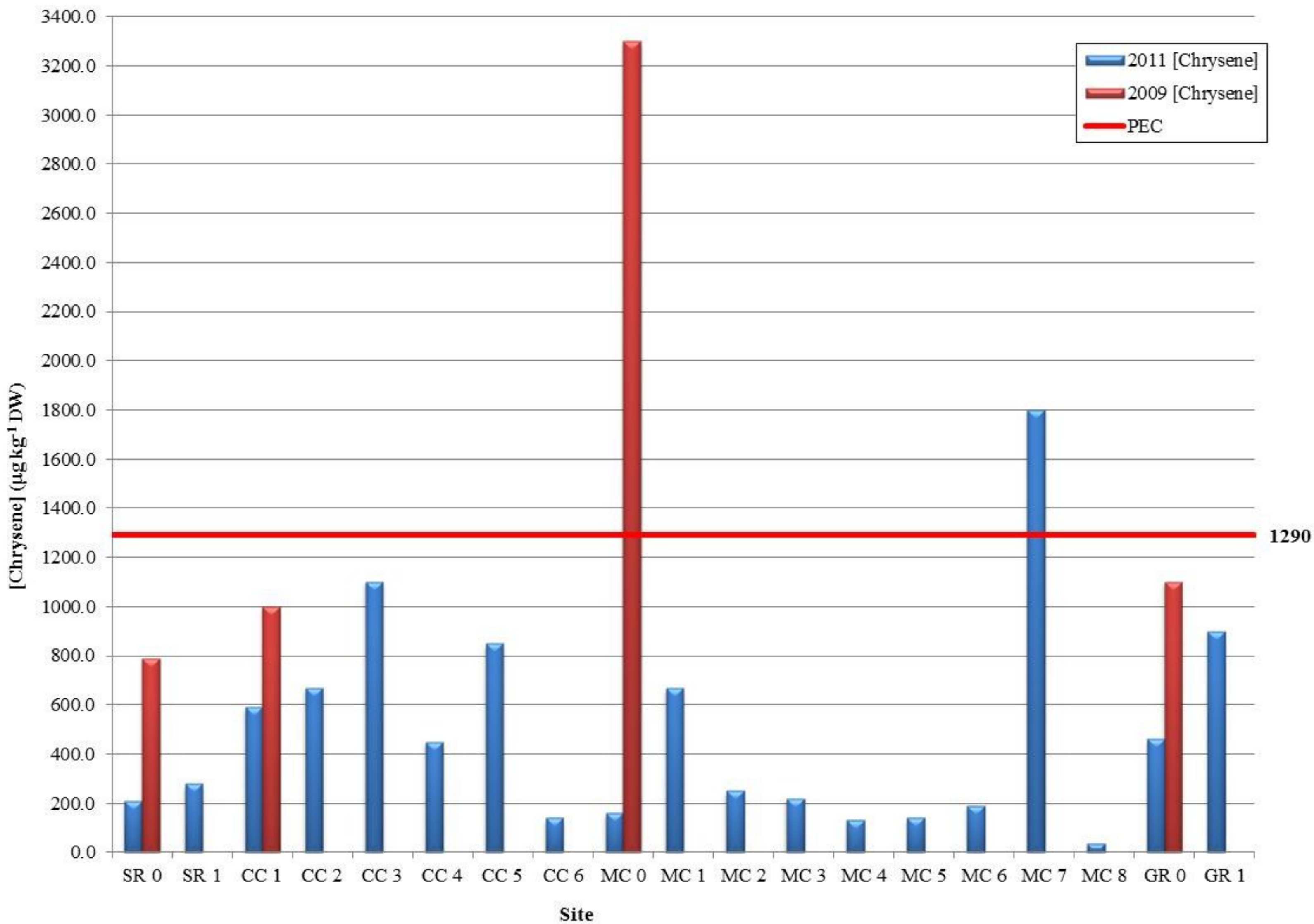

Figure 11. Chrysene concentrations in the Presque Isle Bay watershed: 2009—2011

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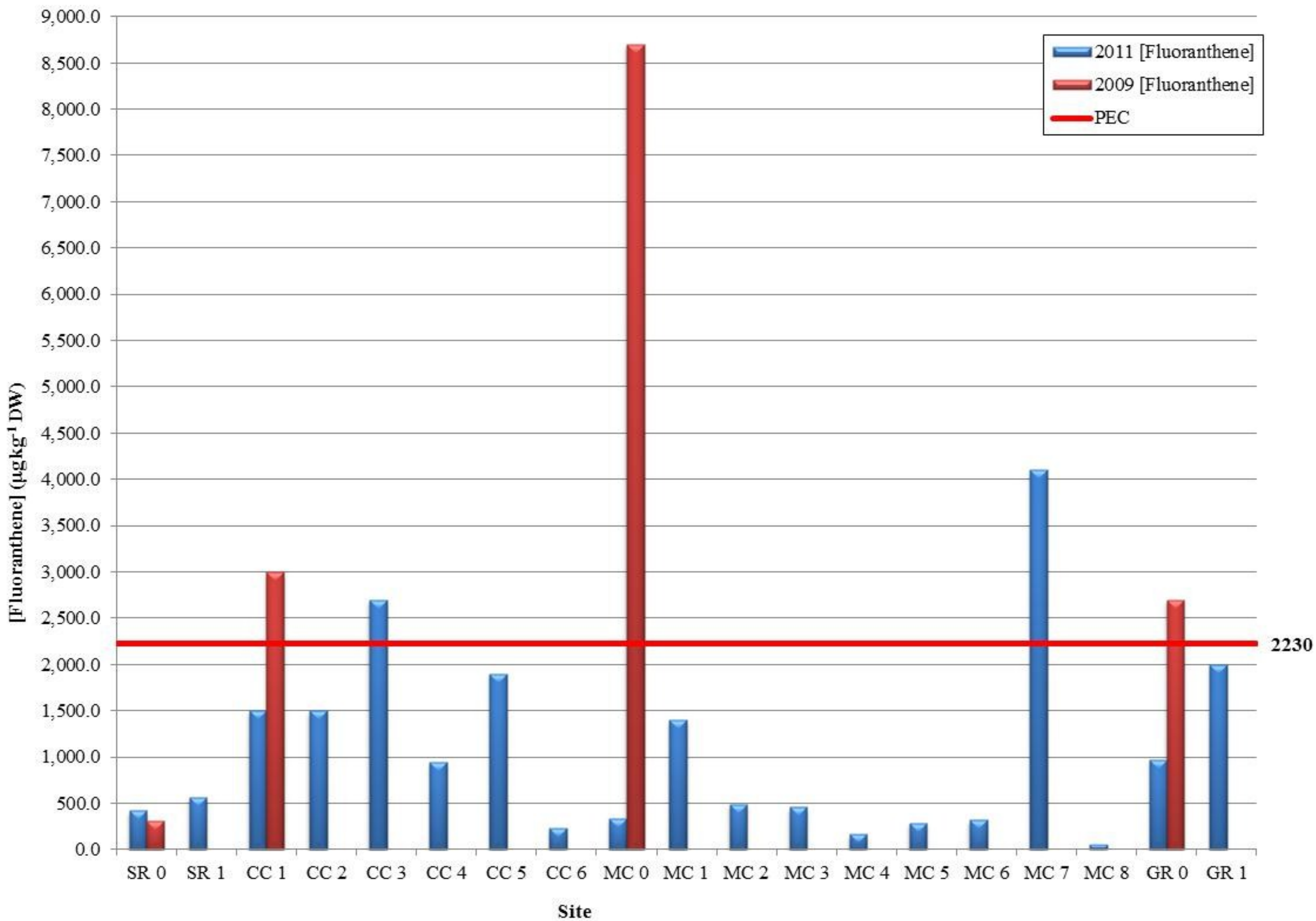

Figure 12. Fluoranthene concentrations in the Presque Isle Bay watershed: 2009—2011

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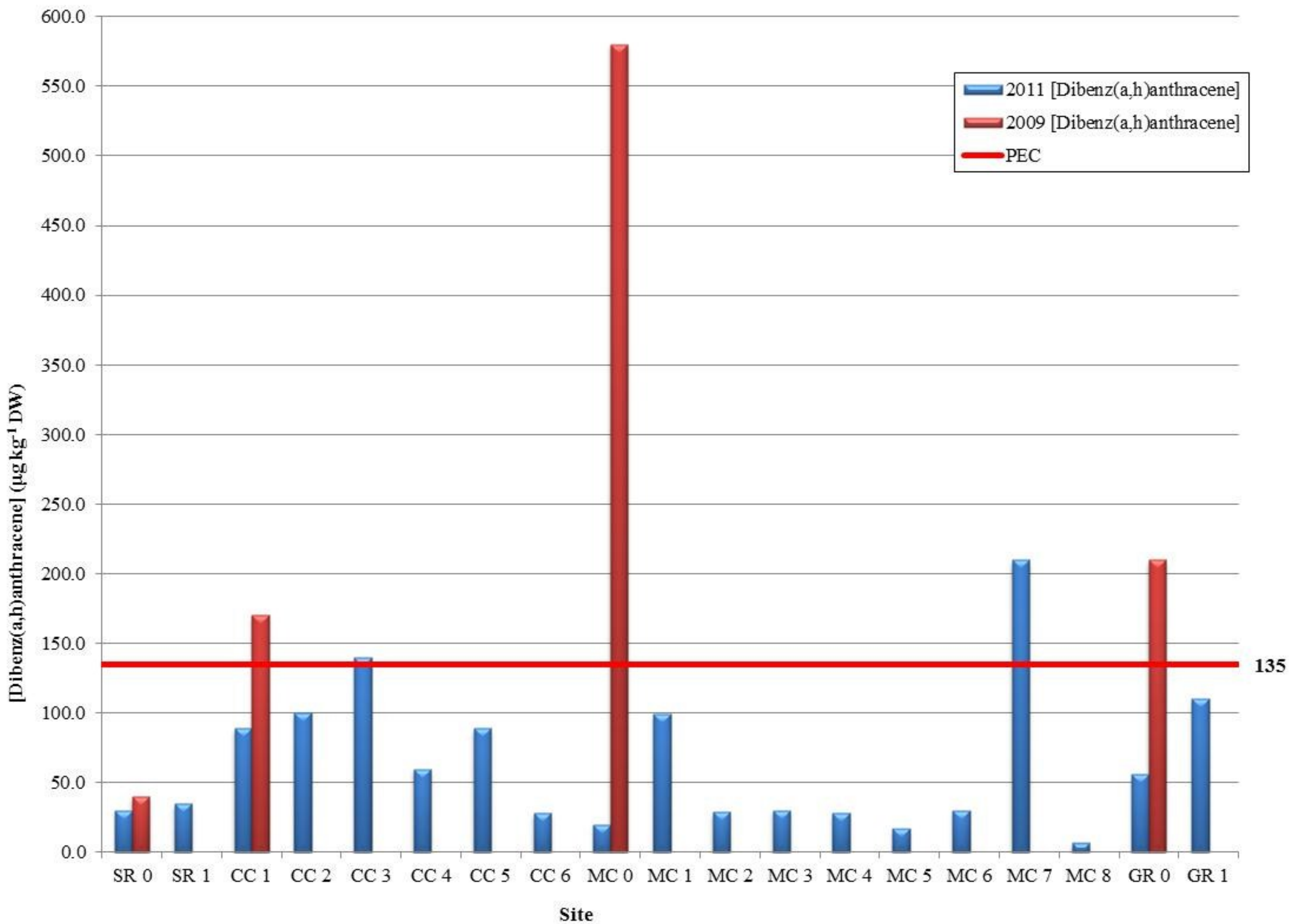

Figure 13. Dibenz(a,h)anthracene concentrations in the Presque Isle Bay watershed: 2009—2011

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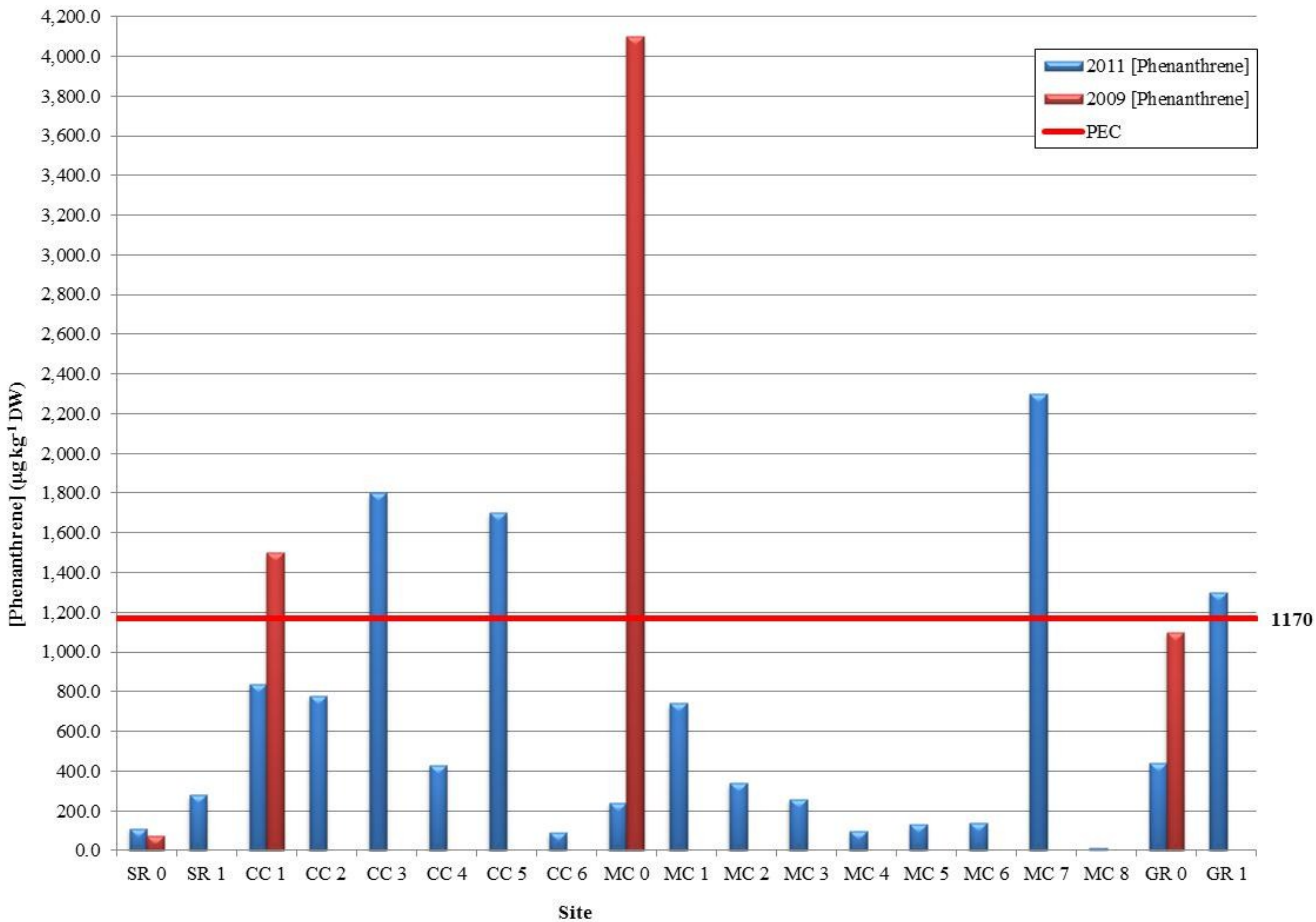

Figure 14. Phenanthrene concentrations in the Presque Isle Bay watershed: 2009—2011

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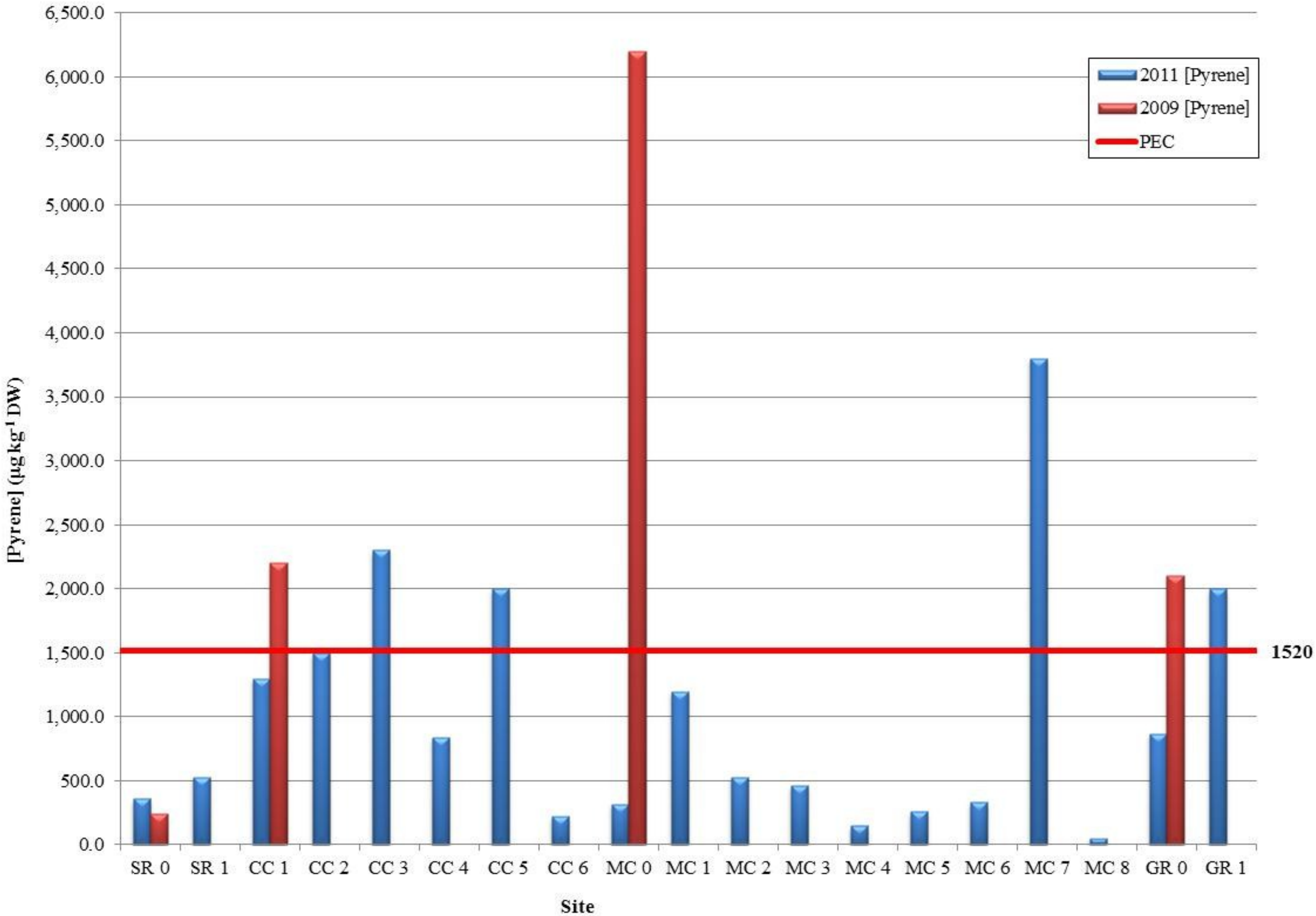

Figure 15. Pyrene concentrations in the Presque Isle Bay watershed: 2009—2011

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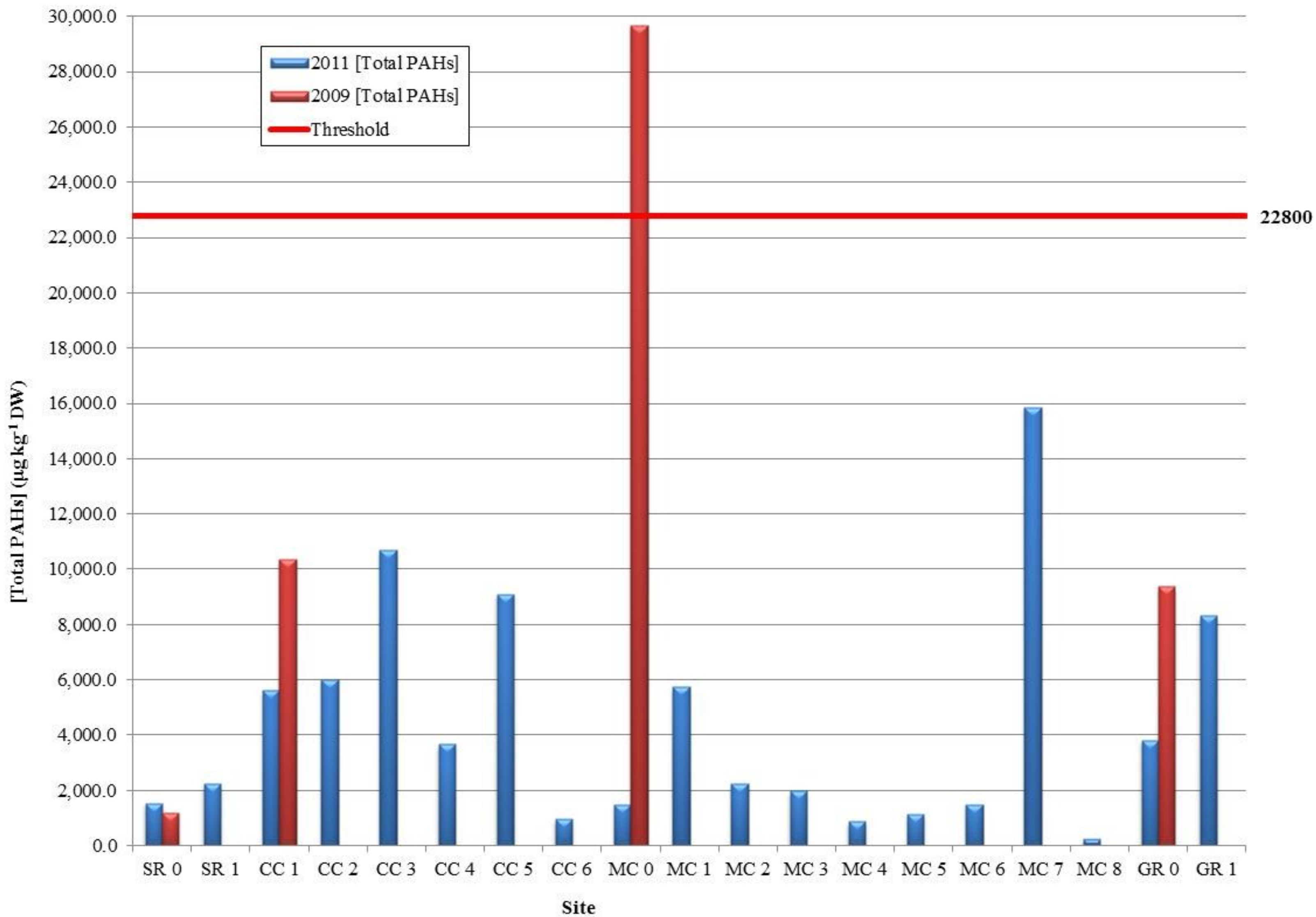

Figure 16. Total PAH concentrations in the Presque Isle Bay watershed: 2009—2011

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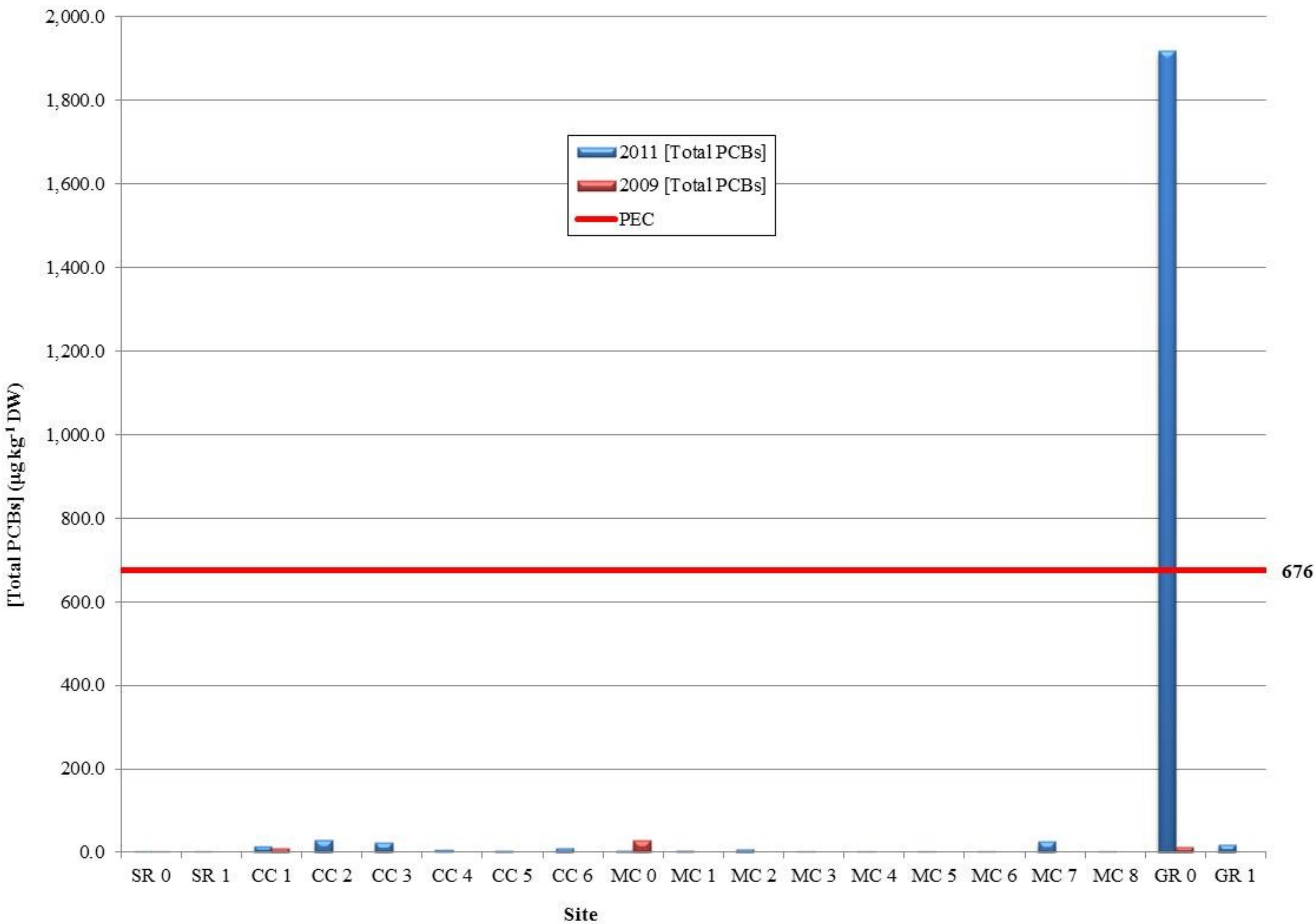

Figure 17. Total PCB concentrations in the Presque Isle Bay watershed: 2009—2011

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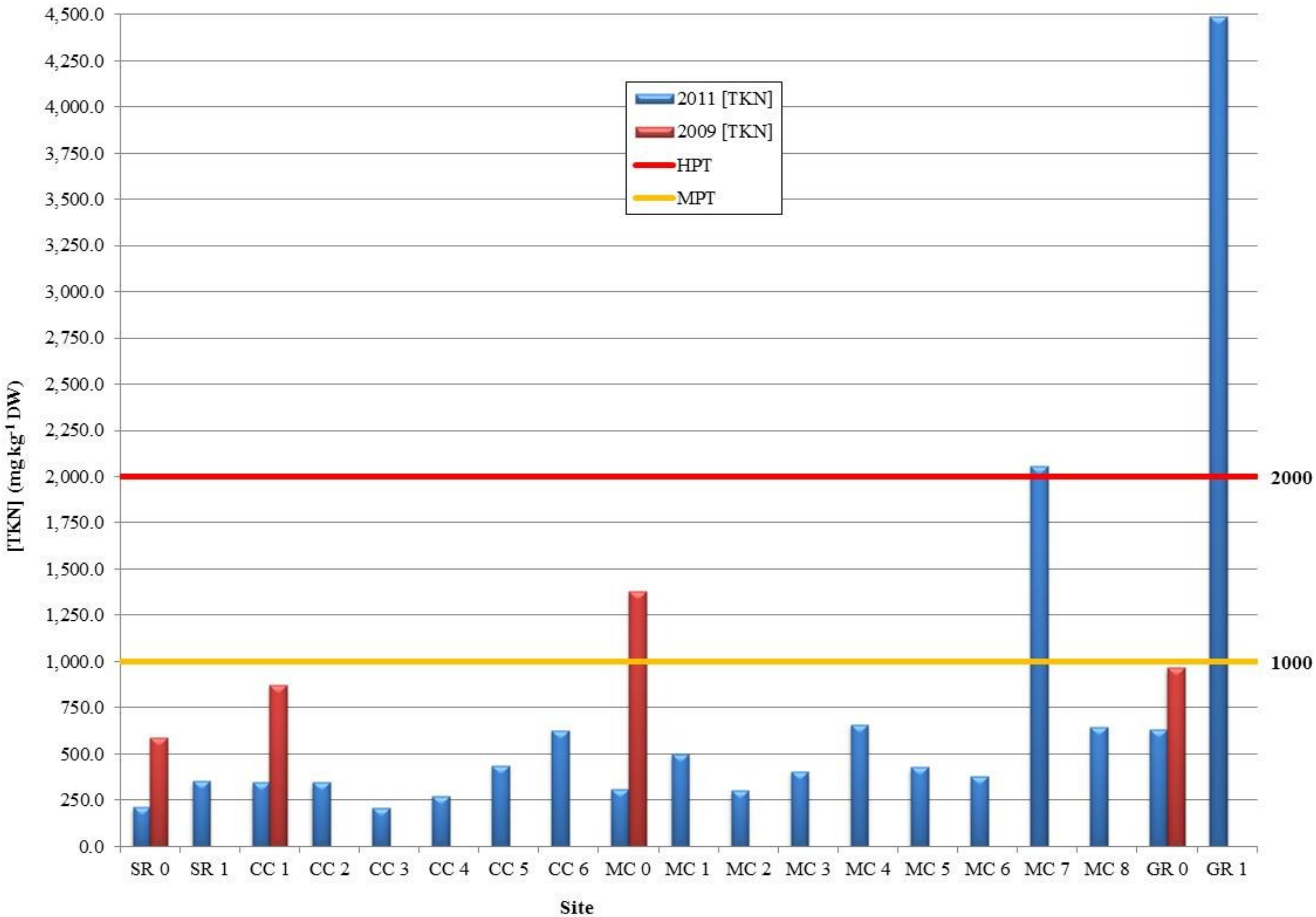

Figure 18. TKN concentrations in the Presque Isle Bay watershed: 2009—2011

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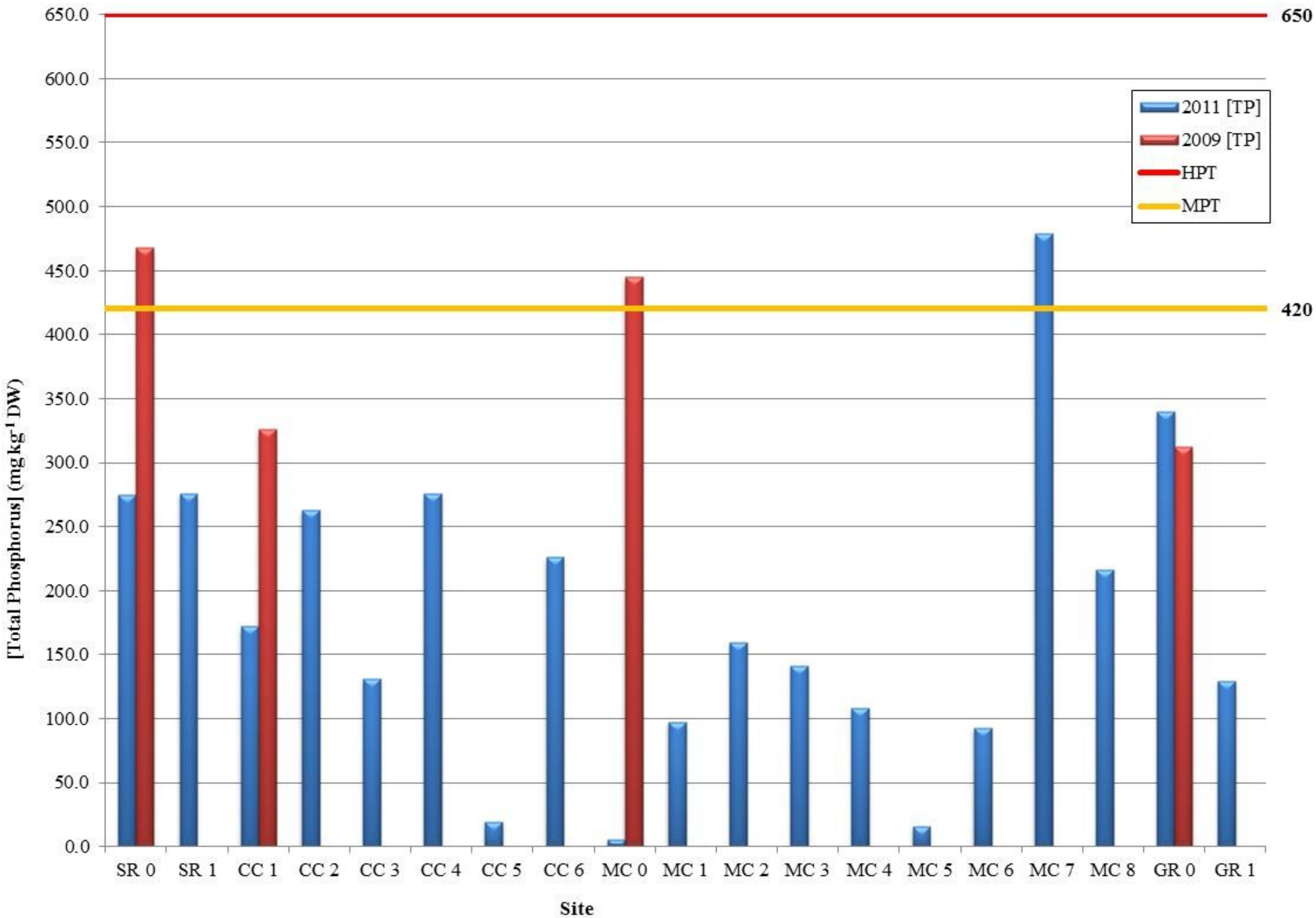

Figure 19. Total phosphorus concentrations in the Presque Isle Bay watershed: 2009—2011

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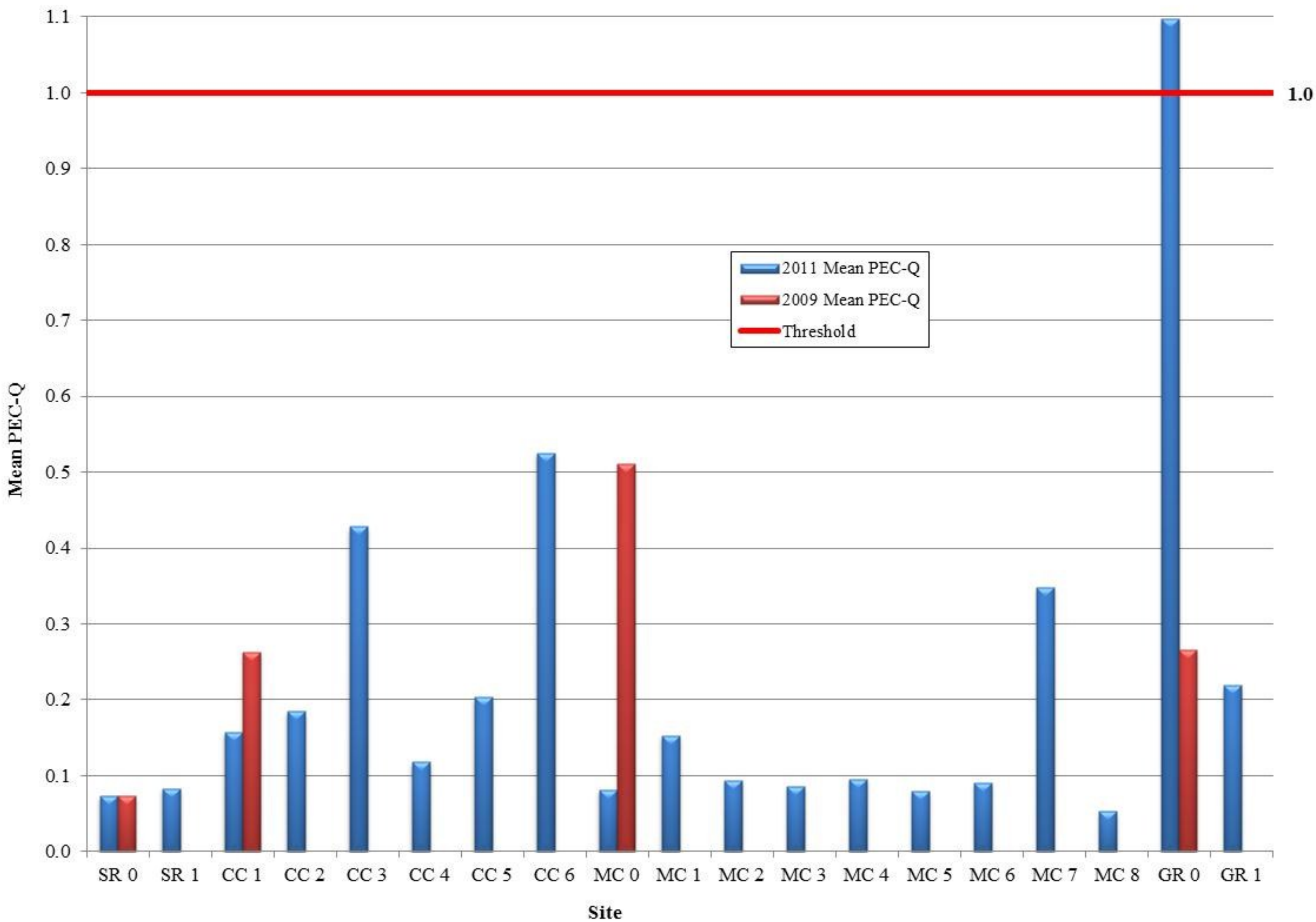

Figure 20. Mean PEC-Q values in the Presque Isle Bay watershed: 2009—2011

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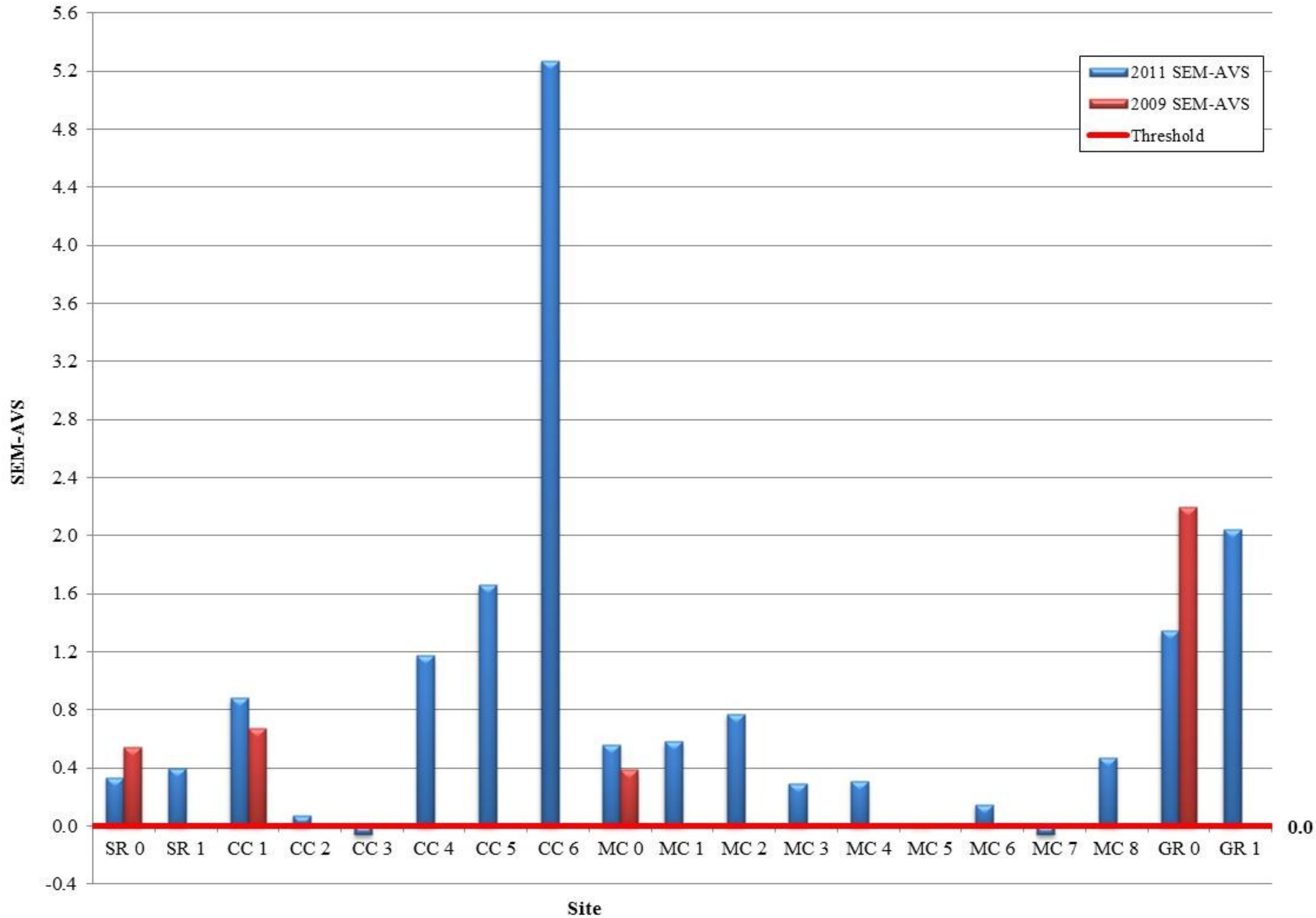

Figure 21. SEM-AVS values in the Presque Isle Bay watershed: 2009—2011

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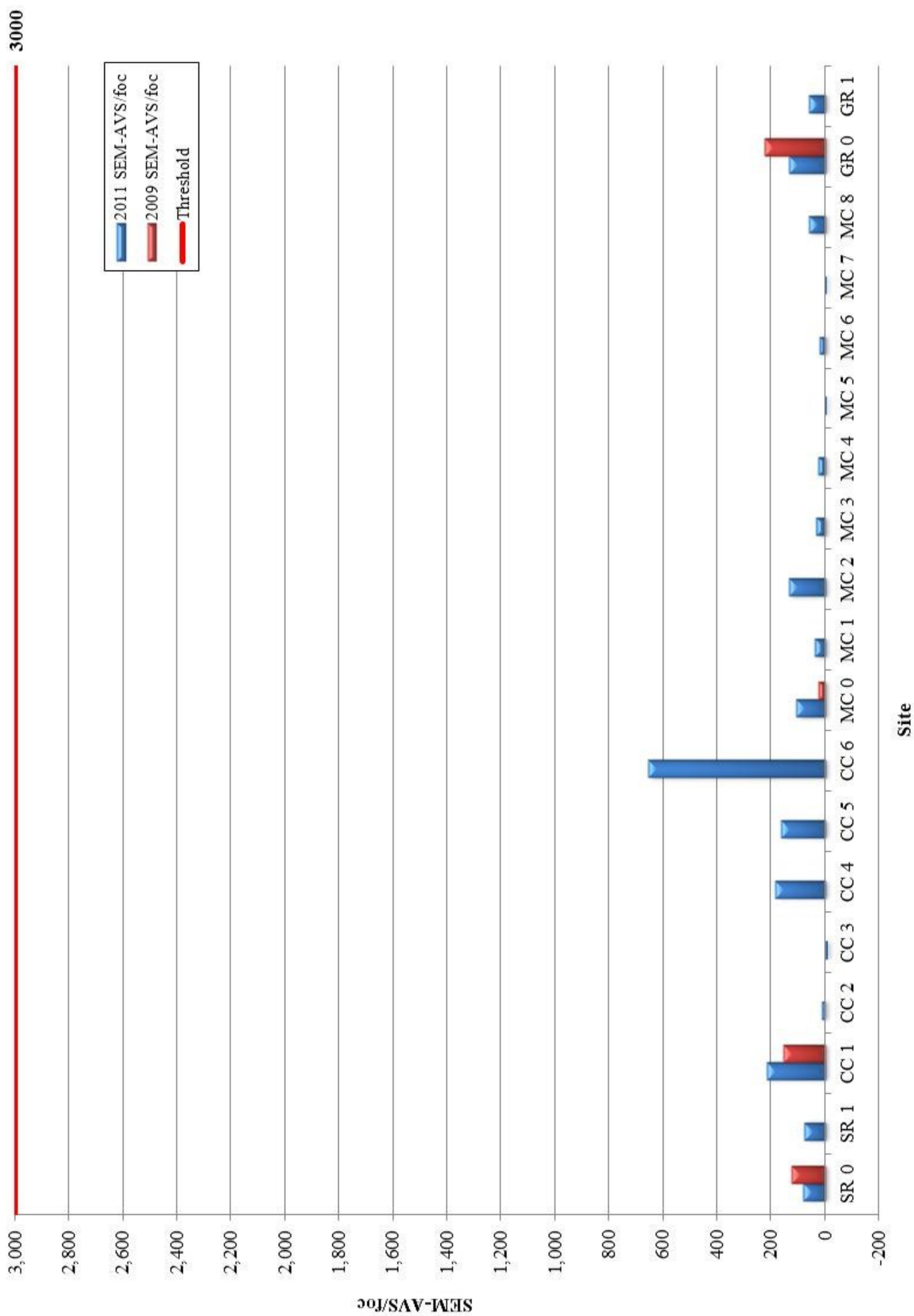

Figure 22. SEM-AVS/f_{oc} values in the Presque Isle Bay watershed: 2009—2011

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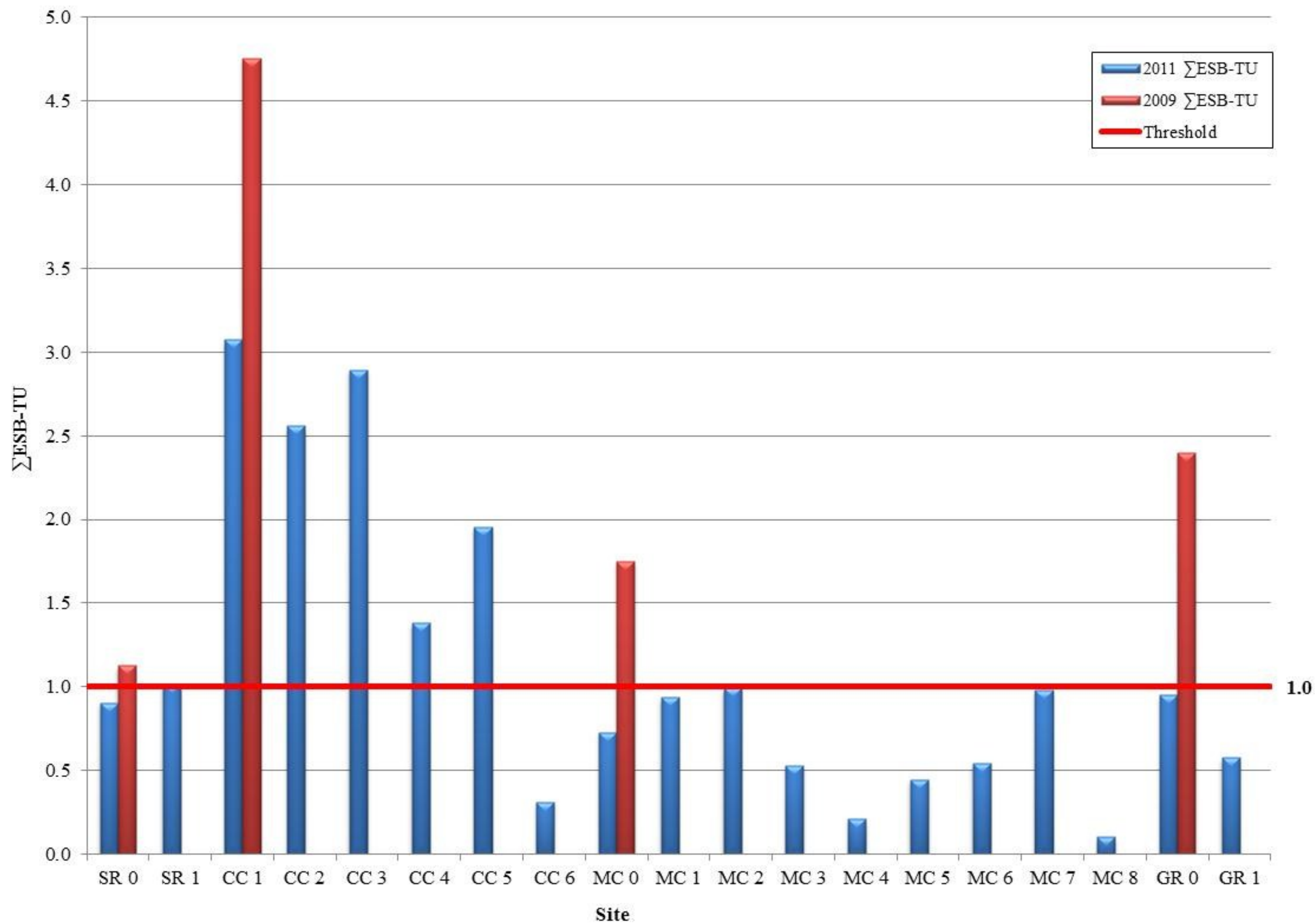

Figure 23. ΣESB-TU values in the Presque Isle Bay watershed: 2009—2011

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APPENDIX B: TABLES

Table 1. 2011 Presque Isle Bay tributary sediment quality evaluation sampling locations

Stream	Site*	Date	Latitude	Longitude
Mill Creek	MC 0	May 11, 2011	42.13972	-80.07807
Mill Creek	MC 1	May 11, 2011	42.10565	-80.07300
Mill Creek	MC 2	May 11, 2011	42.09383	-80.07074
Mill Creek	MC 3	May 11, 2011	42.08546	-80.07150
Mill Creek	MC 4	May 11, 2011	42.07718	-80.05161
Mill Creek	MC 5	May 11, 2011	42.09206	-80.05542
Mill Creek	MC 6	May 11, 2011	42.10289	-80.02686
Mill Creek	MC 7	May 11, 2011	42.10300	-80.02760
Mill Creek	MC 8	May 11, 2011	42.09076	-80.01552
Cascade Creek	CC 1	May 10, 2011	42.12636	-80.11086
Cascade Creek	CC 2	May 10, 2011	42.11683	-80.11703
Cascade Creek	CC 3	May 10, 2011	42.11359	-80.11610
Cascade Creek	CC 4	May 10, 2011	42.11131	-80.12044
Cascade Creek	CC 5	May 10, 2011	42.10590	-80.13152
Cascade Creek	CC 6	May 10, 2011	42.10170	-80.13084
Scott Run	SR 0	May 10, 2011	42.11180	-80.15488
Scott Run	SR 1	May 10, 2011	42.11232	-80.15416
Garrison Run	GR 0	May 10, 2011	42.14357	-80.07569
Garrison Run	GR 1	May 10, 2011	42.14168	-80.07315

* MC 1, MC 2, MC 3, MC 4, MC 5, MC 6, MC 7, MC 8, CC 1, CC 2, CC 3, CC4, CC 5, CC 6, SR 1, and GR 1 were previously sampled by Diz and Johnson (2002) and MC 0, SR 0, and GR 0 were previously sampled by Rafferty (2010)

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Table 2. 2011 Chemicals of Potential Concern (COPCs)

COPCs
Nitrosamines (µg/kg)
N-Nitrosodiethylamine; N-Nitrosodimethylamine; N-Nitrosodi-n-propylamine; N-Nitrosodi-n-butylamine; N-Nitrosomethylethylamine; N-Nitrosomorpholine; N-Nitrosopiperidine; N-Nitrosopyrrolidine; and N-Nitrosodiphenylamine
Pesticides (µg/kg)
Aldrin; gamma-BHC; Chlordane; 4,4'-DDD; 2,4'-DDD; 4,4'-DDE; 2,4'-DDE; 4,4'-DDT; 2,4'-DDT; Dieldrin; Endosulfan I, Endosulfan II; Endrin; Heptachlor; Heptachlor epoxide; Hexachlorobenzene; Hexachlorocyclopentadiene; Methoxychlor; Mirex, Hexachlorobenzene; and trans-nonachlor
Metals (mg/kg)
Antimony; Arsenic; Barium; Beryllium; Cadmium; Chromium; Copper; Lead; Mercury; Nickel; and Zinc
Polychlorinated Biphenyls (PCBs) (µg/kg)
PCB-8; PCB-18; PCB-28; PCB-44; PCB-52; PCB-66; PCB-87; PCB-101; PCB-105; PCB-118; PCB-128; PCB-138; PCB-153; PCB-170; PCB-180; PCB-187; PCB-195; PCB-206; and PCB-209
Polycyclic Aromatic Hydrocarbons (PAHs) (µg/kg)
Acenaphthene; Acenaphthylene; Anthracene; C1-phenan/anthracenes; C2-phenan/anthracenes; C3-phenan/anthracenes; C4-phenan/anthracenes; Benz(a)anthracene; Benzo(a)pyrene; Benzo(b)fluoranthene; Benzo(e)pyrene; Benzo(g,h,i)perylene; Benzo(k)fluoranthene; Chrysene; C1-chrysenes; C2-chrysenes; C3-chrysenes; C4-chrysenes; Dibenz(a,h)anthracene; Fluoranthene; Fluorene; C1-fluorenes; C2-fluorenes; C3-fluorenes; Indeno(1,2,3-c,d)pyrene; Naphthalene; C1-naphthalenes; C2-naphthalenes; C3-naphthalenes; C4-naphthalenes; 2-methylnaphthalene; 1-methylnaphthalene; 2,3,5 trimethylnaphthalne; 2,6 dimethylnaphthalene; Biphenyl; Perylene; Phenanthrene; 1-methylphenanthrene; Pyrene; C1-fluoran/pyrenes; C2; fluoran/pyrenes; C3-fluoran/pyrenes; Dibenzothiophene; C1-dibenzothiophene; C2-dibenzothiophene; and C3-debenzothiophene; total PAHs
General Chemistry
AVS/SEM; n-hexane extractible material (oil and grease); nitrate/nitrite as N; total nitrogen; total kjeldahl nitrogen; percent solids; total organic carbon; phosphorus; and grain size

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Table 3. Historical Presque Isle Bay tributary sediment data: 2001 - 2011

Site	Year*	Cadmium	Copper	Lead	Nickel	Zinc	Oil and
		Concentrations of COPCs (mg/kg)**					
SR 0	2011	0.17	18.1	9.1	13.6	**78.2**	**180.0**
	2009	**0.22**	**18.9**	**11.4**	**16.6**	77.3	101.0
SR 1	2011	**0.18**	15.8	9.7	12.7	69.6	190.0
	2001	0.00	**18.1**	**17.4**	**93.5**	**78.7**	**4591.0**
CC 1	2011	0.26	25.7	27.0	19.3	95.4	874.0
	2009	**4.20**	29.7	31.0	20.0	**219.0**	1330.0
	2001	1.60	**42.3**	**42.5**	**94.8**	159.4	**7390.0**
CC 2	2011	**0.48**	31.8	65.4	17.9	146.0	1480.0
	2001	0.30	**38.3**	**76.6**	**112.9**	**151.7**	**3886.0**
CC 3	2011	0.32	**713.0**	**83.3**	20.2	118.0	1670.0
	2001	**0.50**	65.6	58.8	**22.6**	**165.9**	**3182.0**
CC 4	2011	**0.35**	23.6	25.7	14.9	110.0	492.0
	2001	0.00	**41.8**	**41.5**	**134.3**	**198.3**	**9137.0**
CC 5	2011	0.26	30.4	23.9	17.2	113.0	1090.0
	2001	**0.50**	**145.3**	**130.1**	**191.4**	**209.3**	**17280.0**
CC 6	2011	**0.83**	**1580.0**	92.4	58.9	257.0	412.0
	2001	0.00	84.8	**100.9**	**72.2**	**449.9**	**14905.0**
MC 0	2011	0.16	21.8	11.6	17.0	65.4	565.0
	2009	**0.32**	**30.2**	**52.9**	**19.9**	**133.0**	**1760.0**
MC 1	2011	**0.19**	17.5	24.8	18.7	79.4	484.0
	2001	0.00	**62.6**	**36.9**	**24.2**	**161.2**	**22060.0**
MC 2	2011	**0.15**	15.6	22.6	15.5	78.4	252.0
	2001	0.00	**57.0**	**51.2**	**25.4**	**154.3**	**9147.0**
MC 3	2011	**0.19**	13.9	17.6	14.9	59.9	272.0
	2001	0.00	**22.5**	**17.8**	**24.8**	**137.8**	**17513.0**
MC 4	2011	**0.28**	29.3	39.6	18.7	93.9	192.0
	2001	0.00	**30.9**	**28.5**	**25.1**	**147.5**	**4153.0**
MC 5	2011	**0.19**	14.3	13.0	19.3	58.1	84.4
	2001	0.00	**33.6**	**21.8**	**33.3**	**164.0**	**14353.0**
MC 6	2011	**0.20**	15.7	14.4	18.1	62.7	117.0
	2001	0.00	**23.6**	**35.2**	**25.4**	**148.2**	**14528.0**
MC 7	2011	**0.30**	20.8	30.9	14.4	93.1	1730.0
	2001	0.00	**31.1**	**35.2**	**25.0**	**283.3**	**6873.0**
MC 8	2011	**0.14**	8.8	9.8	13.5	47.8	96.3
	2001	0.00	**19.6**	**16.1**	**25.4**	**156.8**	**6178.0**
GR 0	2011	**0.71**	23.1	**55.1**	14.3	104.0	**2610.0**
	2009	0.66	**25.8**	49.7	**18.8**	**131.0**	2200.0
GR 1	2011	0.35	34.9	41.1	20.6	108.0	4930.0
	2001	**5.60**	**105.3**	**153.5**	**59.8**	**324.9**	**9997.0**

* 2009 data was reported by Rafferty and Boughton (2011) and 2001 data was reported by Diz and Johnson (2002)

** Values in bold represent the higher concentration for the indicated COPC and site

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Table 4. Selected sediment quality guidelines (SQG) for whole sediment for evaluating the effects of chemicals of potential concern on the benthic invertebrate community

Chemical of Potential Concern	SQG	Type*	Source
Metals (mg/kg)			
Antimony	25	SEL	NYSDEC 1999
Arsenic	33	PEC	MacDonald *et al. 2000*
Barium	60	HPT	USEPA 1977
Cadmium	4.98	PEC	MacDonald *et al. 2000*
Chromium	111	PEC	MacDonald *et al. 2000*
Copper	149	PEC	MacDonald *et al. 2000*
Lead	128	PEC	MacDonald *et al. 2000*
Mercury	1.06	PEC	MacDonald *et al. 2000*
Nickel	48.6	PEC	MacDonald *et al. 2000*
Zinc	459	PEC	MacDonald *et al. 2000*
PAHs (µg/kg)			
Acenaphthene	88.9	PEL	CCME 1999
Acenaphthylene	128	PEL	CCME 1999
Anthracene	845	PEC	MacDonald *et al. 2000*
Benz(a)anthracene	1050	PEC	MacDonald *et al. 2000*
Benzo(a)pyrene	1450	PEC	MacDonald *et al. 2000*
Chrysene	1290	PEC	MacDonald *et al. 2000*
Dibenz(a,h)anthracene	135	PEL	CCME 1999
Fluoranthene	2230	PEC	MacDonald *et al. 2000*
Fluorene	536	PEC	MacDonald *et al. 2000*
2-Methylnaphthalene	201	PEL	CCME 1999
Napthalene	561	PEC	MacDonald *et al. 2000*
Phenanthrene	1170	PEC	MacDonald *et al. 2000*
Pyrene	1520	PEC	MacDonald *et al. 2000*
Total PAHs	22800	PEC	MacDonald *et al. 2000*
PCBs (µg/kg)			
Total PCBs	676	PEC	MacDonald *et al. 2000*
Organochlorine Pesticides (µg/kg)			
Chlordane	17.6	PEC	MacDonald *et al. 2000*
Sum DDD	28	PEC	MacDonald *et al. 2000*
Sum DDE	31.3	PEC	MacDonald *et al. 2000*
Sum DDT	62.9	PEC	MacDonald *et al. 2000*
DDT (total)	572	PEC	MacDonald *et al. 2000*
Dieldrin	61.8	PEC	MacDonald *et al. 2000*
Endrin	207	PEC	MacDonald *et al. 2000*
Other (mg/kg)			
Oil and Grease	2000	SEL	USEPA 1977
Total Kjeldahl Nitrogen	< 1000[a]; 1000-2000[b]; > 2000[c]	SQG	USEPA 1977
Total Phosphorus	< 420[a]; 420-650[b]; > 650[c]	SQG	USEPA 1977

SEL = severe effect level; PEC = probable effect concentration; HTP = heavily polluted threshold; PEL = probable effect level; SQG = sediment quality guideline

a = non-polluted; b = moderately polluted; c = heavily polluted

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Table 5. 2011 sediment quality guideline (SQG) exceedances

	SQG Exceedance																		
COPC	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	GR0	GR1
Antimony																			
Arsenic																			
Barium					X			X								X		X	
Cadmium																			
Chromium																			
Copper					X			X											
Lead																			
Mercury																			
Nickel								X											
Zinc																			
Acenaphthene					X		X									X			
Acenaphthylene																			
Anthracene																			
Benz(a)anthracene																X			
Benzo(a)pyrene																X			
Chrysene																X			
Dibenz(a,h)anthracene					X											X			
Fluoranthene					X											X			
Fluorene																			
2-Methylnaphthalene																			
Napthalene																			
Phenanthrene					X		X									X			X
Pyrene					X		X									X			X
Total PAHs																			
Total PCBs																		X	
Chlordane																			
Sum DDD																			
Sum DDE																			
Sum DDT																			
DDT (total)																			
Dieldrin																			
Endrin																			
Oil and Grease																		X	X
Total Kjeldahl Nitrogen*																X			X
Total Phosphorus*																X			

*SQG was considered to be exceeded if the concentration exceeded the moderately polluted threshold

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Table 6. 2009 sediment quality guideline (SQG) exceedances

	SQG Exceedances			
COPC	SR0	CC1	MC0	GR0
Antimony				
Arsenic				
Barium				X
Cadmium				
Chromium				
Copper				
Lead				
Mercury				
Nickel				
Zinc				
Acenaphthene			X	
Acenaphthylene				
Anthracene				
Benz(a)anthracene			X	
Benzo(a)pyrene			X	
Chrysene			X	
Dibenz(a,h)anthracene		X	X	X
Fluoranthene		X	X	X
Fluorene				
2-Methylnaphthalene				
Napthalene				
Phenanthrene		X	X	
Pyrene		X	X	X
Total PAHs			X	
Total PCBs				
Chlordane				
Sum DDD				
Sum DDE				
Sum DDT				
DDT (total)				
Dieldrin				
Endrin				
Oil and Grease				X
Total Kjeldahl Nitrogen*			X	
Phosphorus*	X		X	

*SQG was considered to be exceeded if the concentration exceeded the moderately polluted

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Table 7. 2001 sediment quality guidline (SQG) exceedances

	SQG Exceedances															
COPC	SR1	CC1	CC2	CC3	CC4	CC5	CC6	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	GR1
Cadmium																X
Copper																
Lead						X										X
Nickel	X	X	X	X		X	X									X
Zinc																
Oil and Grease	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

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Table 8. Historial mean PEC-Q data: 2009 - 2011

	2011 Mean PEC-Q Data				
Site	Metal Mean PEC-Q	PCB Mean PEC -Q	PAH Mean PEC -Q	2011 Mean PEC -Q	2009 Mean PEC -Q
SR 0	0.147949	0.003493	0.067246	0.072896	0.074135
SR 1	0.148921	0.004345	0.097588	0.083618	
CC 1	0.206839	0.020926	0.246154	0.157973	0.263516
CC 2	0.247992	0.044133	0.262882	0.185002	
CC 3	0.780103	0.035639	0.468947	0.428230	
CC 4	0.183071	0.009265	0.161053	0.117796	
CC 5	0.204103	0.006772	0.399123	0.203333	
CC 6	1.517755	0.015719	0.042452	0.525309	
MC 0	0.173891	0.006308	0.065645	0.081948	0.511391
MC 1	0.200269	0.006180	0.251934	0.152795	
MC 2	0.172213	0.012142	0.097614	0.093990	
MC 3	0.168016	0.002704	0.087263	0.085995	
MC 4	0.246570	0.001837	0.038452	0.095620	
MC 5	0.187599	0.001638	0.049522	0.079586	
MC 6	0.205815	0.001626	0.065746	0.091062	
MC 7	0.309435	0.039093	0.696228	0.348252	
MC 8	0.147061	0.002089	0.010587	0.053246	
GR 0	0.288395	2.837846	0.167316	1.097852	0.266641
GR 1	0.262930	0.028636	0.365263	0.218943	

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Table 9. SEM-AVS ratios: 2009 - 2011

2011 SEM-AVS Data								
Site	SEM (µM/g)	AVS (µM/g)	SEM-AVS	SEM/AVS	f_{oc}	SEM-AVS/ f_{oc}	SEM-AVS (2009)	SEM-AVS/ f_{oc} (2009)
SR 0	0.9137	0.58	0.3337	1.5753	0.00420	79.45	0.5449	123.2805
SR 1	1.0047	0.61	0.3947	1.6470	0.00514	76.79		
CC 1	2.5815	1.70	0.8815	1.5185	0.00407	216.58	0.6751	153.7813
CC 2	2.0726	2.00	0.0726	1.0363	0.00536	13.54		
CC 3	2.2418	2.30	-0.0582	0.9747	0.00805	-7.23		
CC 4	1.7818	0.61	1.1718	2.9210	0.00640	183.09		
CC 5	2.2416	0.58	1.6616	3.8648	0.01030	161.32		
CC 6	7.0729	1.80	5.2729	3.9294	0.00806	654.21		
MC 0	1.1405	0.58	0.5605	1.9664	0.00527	106.36	0.3854	24.5478
MC 1	1.1913	0.61	0.5813	1.9530	0.01490	39.01		
MC 2	1.3709	0.60	0.7709	2.2848	0.00572	134.77		
MC 3	0.9125	0.62	0.2925	1.4718	0.00912	32.07		
MC 4	0.9406	0.63	0.3106	1.4930	0.01150	27.01		
MC 5	0.5916	0.60	-0.0084	0.9860	0.00620	-1.35		
MC 6	0.7594	0.61	0.1494	1.2449	0.00698	21.40		
MC 7	1.1408	1.20	-0.0592	0.9507	0.03580	-1.65		
MC 8	1.0703	0.60	0.4703	1.7838	0.00770	61.08		
GR 0	1.9542	0.61	1.3442	3.2036	0.00995	135.10	2.1998	221.9778
GR 1	2.6827	0.64	2.0427	4.1917	0.03380	60.43		

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Table 10. ΣESB-TU data: 2009 - 2011

Parameter		
Site	∑ESB-TU (2011)	∑ESB-TU (2009)
SR 0	0.904377164	1.1261
SR 1	1.013423891	
CC 1	3.074828858	4.75569
CC 2	2.560111742	
CC 3	2.895928163	
CC 4	1.37979004	
CC 5	1.95183661	
CC 6	0.314243506	
MC 0	0.729347362	1.75326
MC 1	0.938171793	
MC 2	0.994694054	
MC 3	0.530604575	
MC 4	0.211810681	
MC 5	0.446560398	
MC 6	0.546917151	
MC 7	0.979852219	
MC 8	0.105516899	
GR 0	0.950289017	2.39855
GR 1	0.578782096	

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APPENDIX C: MAPS

Map 1: Tributaries of Presque Isle Bay

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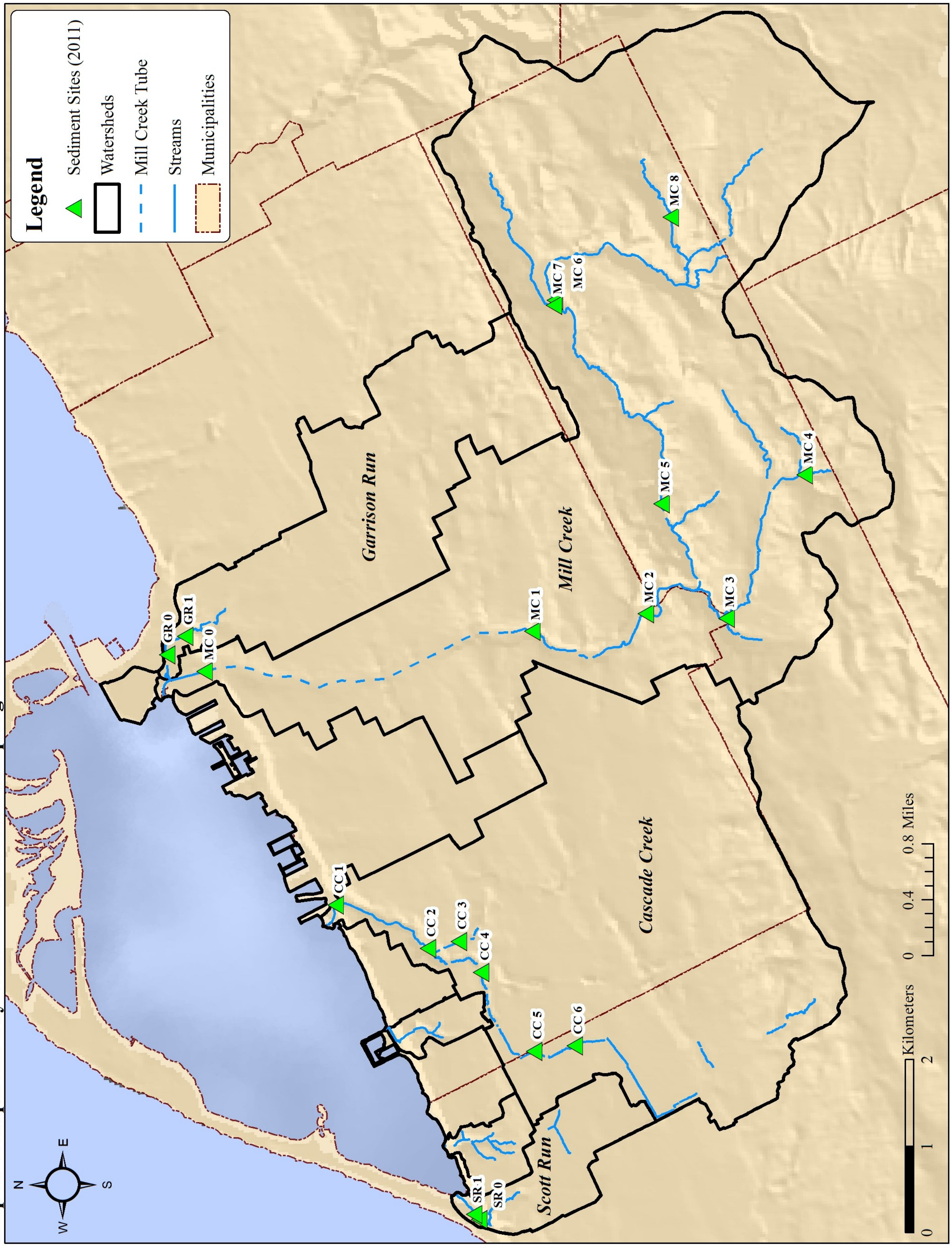
Map 2: Presque Isle Bay Watershed Sediment Sampling Locations



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APPENDIX D: 2011 SEDIMENT CHEMISTRY DATA

Appendix D-1. 2011 Presque Isle Bay tributary sediment pesticide data

	[Pesticide] ($\mu g\ kg^{-1}$)																		
Pesticide	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
Aldrin	2.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lindane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
4,4'-DDD	1.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.64	ND	ND	ND	ND	ND	ND	ND
2,4'-DDD	ND	ND	5.10	7.10	4.10	ND	ND	0.92	1.60	1.40	ND	0.58	0.34	0.20	ND	ND	ND	ND	ND
Sum DDD*	1.274	0.205	5.750	7.780	4.770	1.020	0.980	1.060	2.280	2.080	0.190	1.220	0.480	0.340	0.217	0.202	0.205	1.410	0.204
4,4'-DDE	2.90	ND	ND	ND	ND	2.20	1.50	1.10	ND	1.70	0.47	1.70	0.70	0.67	0.57	0.60	0.70	3.60	0.48
2,4'-DDE	ND	ND	ND	0.66	ND	ND	ND	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sum DDE**	3.010	0.260	1.210	1.440	1.260	2.700	1.980	1.260	1.270	2.180	0.563	1.798	0.798	0.770	0.670	0.257	0.800	4.290	0.579
4,4'-DDT	0.40	ND	3.60	8.60	2.90	ND	ND	0.63	0.78	ND	ND	1.10	ND	ND	ND	ND	ND	ND	ND
2,4'-DDT	0.51	ND	ND	ND	ND	ND	ND	ND	ND	0.72	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sum DDT***	0.910	0.253	4.030	9.050	3.340	1.260	1.210	0.722	1.230	1.500	0.236	1.192	0.251	0.253	0.266	0.250	0.253	1.740	0.252
Total DDT****	5.194	0.718	10.990	18.270	9.370	4.980	4.170	3.042	4.780	5.760	0.989	4.210	1.529	1.363	1.153	0.709	1.258	7.440	1.031
Dieldrin	3.50	2.20	4.00	4.70	1.70	4.80	ND	0.24	1.20	1.30	0.27	4.40	ND	0.21	ND	ND	0.47	ND	ND
Endosulfan I	0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan II	0.36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Endrin	0.81	ND	ND	ND	ND	ND	ND	ND	ND	1.50	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Heptachlor epoxide	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobenzene	ND	ND	ND	ND	ND	ND	ND	ND	16.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methoxychlor	ND	ND	ND	99.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mirex	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
trans-nonachlor	ND	0.30	4.30	2.90	1.30	5.20	0.42	0.45	1.60	2.00	0.31	1.40	0.60	0.38	ND	ND	0.20	ND	ND

* Sum DDD = 4,4'-DDD + 2,4'-DDD; the MDLs were used to calulate Sum DDD when result was ND

** Sum DDE = 4,4'-DDE + 2,4'-DDE; the MDLs were used to calculate Sum DDE when result was ND

*** Sum DDT = 4,4'-DDT + 2,4'-DDT; the MDLs were used to calculate Sum DDT when result was ND

**** Total DDT = Sum DDD + Sum DDE + Sum DDT

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Appendix D-2. 2011 Presque Isle Bay tributary sediment polychlorinated biphenyl (PCBs) data

	[PCBs] (μg kg^{-1})																		
PCB	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
PCB 8	ND	0.17	ND	ND	ND	ND	ND	ND	1900	ND	2.2	ND	ND	ND	ND	ND	ND	1.70	ND
PCB 18	0.21	0.41	ND	ND	ND	ND	0.29	0.56	1.40	1.60	0.22	0.36	1.40	ND	ND	0.08	ND	0.37	0.12
PCB 28	0.32	0.42	0.12	0.25	0.22	0.22	0.29	0.60	1.80	2.20	0.36	0.49	2.50	0.12	ND	ND	ND	0.57	ND
PCB 44	0.190	0.230	0.520	0.850	0.770	0.330	0.170	0.830	1.400	1.400	0.160	0.230	0.830	0.092	ND	ND	ND	0.370	ND
PCB 52	0.27	0.25	1.30	1.90	1.90	0.25	0.22	1.40	1.40	1.50	0.13	0.23	0.82	0.11	ND	ND	ND	0.46	ND
PCB 66	0.15	0.27	0.58	0.87	0.66	1.20	0.17	0.46	1.00	1.10	0.35	0.46	0.96	0.19	ND	ND	ND	0.50	ND
PCB 87	0.13	0.11	1.20	2.20	2.00	0.19	0.20	0.84	0.73	0.80	ND	0.16	0.20	0.11	ND	ND	ND	0.34	0.06
PCB 101	0.180	0.140	1.800	3.400	2.600	ND	0.250	1.100	1.100	1.200	0.100	0.150	0.240	0.086	ND	ND	ND	0.490	0.078
PCB 105	ND	ND	ND	ND	ND	0.79	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 118	0.085	0.082	1.000	1.800	1.700	0.170	0.170	0.640	1.100	1.200	ND	0.120	0.170	0.081	ND	ND	ND	0.450	0.061
PCB 128	ND	ND	0.94	1.90	1.60	0.37	0.38	0.48	0.83	0.96	ND	0.20	ND	ND	ND	ND	ND	2.20	ND
PCB 138	0.14	0.18	2.2	4.4	5.1	0.59	0.57	1.1	1.5	1.8	0.11	0.29	0.3	0.17	ND	ND	0.063	2.000	0.21
PCB 153	0.20	0.21	2.10	4.90	3.40	0.67	0.59	1.10	1.80	1.90	0.11	0.31	0.27	0.20	ND	0.11	ND	3.00	0.16
PCB 170	ND	ND	0.680	1.900	1.200	0.400	0.370	0.400	1.000	0.940	0.053	0.320	0.063	ND	ND	ND	ND	4.700	ND
PCB 180	0.054	0.076	0.570	1.500	0.960	0.290	0.280	0.310	0.780	0.710	ND	0.220	0.076	0.082	ND	ND	ND	3.800	ND
PCB 187	ND	ND	0.67	1.90	1.10	0.40	0.34	0.44	1.30	1.10	ND	0.34	ND	0.15	ND	ND	0.13	3.00	ND
PCB 195	ND	ND	0.091	0.410	0.150	0.079	0.057	ND	0.240	0.290	ND	0.057	ND	ND	ND	ND	ND	1.000	ND
PCB 206	ND	ND	0.180	1.200	0.440	0.110	0.069	0.200	0.650	0.420	ND	0.072	ND	ND	0.093	ND	ND	1.100	ND
PCB 209	0.059	ND	ND	0.310	0.150	ND	ND	ND	0.300	0.130	ND	ND	ND	0.097	0.200	ND	ND	0.300	0.079
Total PCB*	2.361	2.937	14.146	29.834	24.092	6.263	4.578	10.626	1918.4	19.358	4.264	4.178	8.208	1.828	1.242	1.107	1.099	26.427	1.412

* MDLs were used to calculate total PCBs when PCB result was ND

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Appendix D-3. 2011 Presque Isle Bay tributary sediment metal data

	[Metals] (mg kg^{-1})																		
Metal	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
Arsenic	7.2	7.3	7.8	6.9	5.5	5.2	5.0	9.3	6.6	7.2	6.7	7.2	6.2	6.7	10.1	6.4	9.1	13.3	4.7
Barium	29.7	33.5	36	32.9	75.8	34.4	39.9	85.7	73.1	50.4	39.1	44.8	37.4	39.7	52.2	47.6	51	93.2	41
Beryllium	0.20	0.21	0.34	0.29	0.43	0.20	0.22	0.29	0.28	0.26	0.32	0.37	0.30	0.31	0.42	0.40	0.40	0.51	0.32
Cadmium	0.17	0.18	0.26	0.48	0.32	0.35	0.26	0.83	0.71	0.35	0.16	0.19	0.15	0.19	0.28	0.19	0.2	0.3	0.14
Chromium	7.5	6.2	18.4	20.7	15.8	11	16.7	15	19.7	24.6	11.1	11.9	9.5	9.4	11.7	11.2	10.8	11.4	8.8
Copper	18.1	15.8	25.7	31.8	713	23.6	30.4	1580	23.1	34.9	21.8	17.5	15.6	13.9	29.3	14.3	15.7	20.8	8.8
Nickel	13.6	12.7	19.3	17.9	20.2	14.9	17.2	58.9	14.3	20.6	17	18.7	15.5	14.9	18.7	19.3	18.1	14.4	13.5
Lead	9.1	9.7	27	65.4	83.3	25.7	23.9	92.4	55.1	41.1	11.6	24.8	22.6	17.6	39.6	13	14.4	30.9	9.8
Antimony	0.074	0.077	0.170	0.250	0.850	0.130	0.280	0.800	0.250	0.840	0.100	0.140	0.110	0.100	0.250	0.074	1.300	0.250	0.050
Zinc	78.2	69.6	95.4	146.0	118.0	110.0	113.0	257.0	104.0	108.0	65.4	79.4	78.4	59.9	93.9	58.1	62.7	93.1	47.8
Mercury	ND	ND	ND	0.02	0.023	ND	ND	0.038	0.031	0.033	ND	0.019	ND	0.022	0.024	0.027	0.017	0.09	0.019

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Appendix D-4. 2011 Presque Isle Bay tributary sediment polycyclic aromatic hydrocarbon (PAH) data

	[PAH] ($\mu g\ kg^{-1}$)																		
PAH	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
Naphthalene	11.0	11.0	29.0	9.7	51.0	30.0	99.0	4.3	29.0	20.0	4.8	7.9	6.2	3.9	5.5	8.5	8.5	20.0	3.3
C1-Naphthalenes	11.0	11.0	29.0	29.0	42.0	30.0	54.0	6.3	29.0	45.0	13.0	27.0	18.0	11.0	5.5	8.5	8.5	77.0	3.3
C2-Naphthalenes	11.0	11.0	34.0	39.0	64.0	30.0	91.0	17.0	44.0	100.0	45.0	100.0	51.0	24.0	8.9	18.0	19.0	77.0	3.9
C3-Naphthalenes	11.0	16.0	35.0	39.0	52.0	30.0	56.0	15.0	48.0	120.0	42.0	110.0	56.0	25.0	13.0	20.0	32.0	77.0	3.8
C4-Naphthalenes	17.0	24.0	29.0	32.0	42.0	30.0	42.0	8.8	40.0	88.0	23.0	55.0	31.0	19.0	14.0	13.0	20.0	77.0	4.7
2-Methylnaphthalene	11.00	11.00	8.30	11.00	29.00	30.00	50.00	5.10	9.80	22.00	10.00	15.00	8.10	4.70	1.50	3.30	2.20	77.00	0.89
1-Methylnaphthalene	11.0	11.0	7.6	8.8	18.0	30.0	31.0	4.2	8.2	17.0	9.5	16.0	8.7	4.8	1.5	3.5	2.4	77.0	3.3
1,1' Biphenyl	11.0	11.0	29.0	29.0	11.0	30.0	11.0	6.2	29.0	45.0	2.3	27.0	18.0	11.0	5.5	8.5	8.5	77.0	3.3
2,6 Dimethylnaphthalene	11.00	11.00	9.00	7.40	12.00	30.00	18.00	2.90	8.70	19.00	8.00	17.00	8.50	4.00	1.40	2.70	3.30	77.00	0.86
Acenaphthylene	3.2	11.0	29.0	29.0	42.0	30.0	42.0	2.9	29.0	45.0	2.9	8.2	5.3	7.0	2.0	2.2	8.3	77.0	1.5
Acenaphthene	5.5	17.0	39.0	49.0	140.0	19.0	230.0	6.0	30.0	81.0	18.0	49.0	17.0	17.0	1.9	5.9	11.0	100.0	3.3
2,3,5 Trimethylnaphthalene	11.0	11.0	29.0	29.0	42.0	19.0	11.0	2.5	8.1	22.0	6.2	15.0	11.0	4.5	1.6	3.0	5.2	77.0	3.3
Fluorene	6.5	19.0	48.0	55.0	160.0	22.0	260.0	6.6	37.0	120.0	27.0	75.0	35.0	25.0	3.8	8.2	14.0	140.0	1.3
C1-Fluorenes	11.0	11.0	29.0	29.0	42.0	30.0	42.0	6.2	29.0	45.0	9.1	31.0	18.0	11.0	5.5	8.5	8.9	77.0	3.3
C2-Fluorenes	11.0	13.0	29.0	29.0	42.0	30.0	42.0	6.2	29.0	45.0	11.0	33.0	18.0	11.0	6.0	8.5	8.5	77.0	3.3
C3-Fluorenes	15.0	20.0	29.0	29.0	42.0	30.0	42.0	6.2	29.0	46.0	7.9	43.0	18.0	11.0	11.0	8.5	8.6	77.0	3.8
Dibenzothiophene	5.90	15.00	44.00	42.00	97.00	22.00	120.00	5.70	22.00	69.00	16.00	39.00	22.00	16.00	7.20	6.40	6.50	120.00	0.96
C1-Dibenzothiophenes	11.0	11.0	29.0	29.0	42.0	30.0	42.0	6.2	29.0	45.0	14.0	32.0	25.0	11.0	6.8	8.5	8.5	77.0	3.3
C2-Dibenzothiophenes	11.0	11.0	29.0	29.0	42.0	30.0	42.0	7.6	29.0	45.0	13.0	28.0	22.0	11.0	7.9	8.5	8.5	77.0	3.3
C3-Dibenzothiophenes	11.0	11.0	29.0	29.0	42.0	30.0	42.0	6.3	29.0	45.0	11.0	27.0	18.0	11.0	6.2	8.5	8.5	77.0	3.3
C4-Dibenzothiophenes	11	11	29	29	42	30	42	6.2	29	45	7.9	27	18	11	5.5	8.5	8.5	77	3.3
Phenanthrene	110.0	280.0	840.0	780.0	1800.0	430.0	1700.0	90.0	440.0	1300.0	240.0	740.0	340.0	260.0	100.0	130.0	140.0	2300.0	13.0
Anthracene	26.0	31.0	140.0	120.0	320.0	61.0	410.0	15.0	84.0	210.0	64.0	190.0	65.0	62.0	24.0	24.0	45.0	250.0	2.3
C1-Phenan/anthracenes	55.0	73.0	180.0	190.0	340.0	110.0	390.0	39.0	150.0	410.0	93.0	350.0	160.0	92.0	41.0	45.0	100.0	420.0	11.0
C2-Phenan/anthracenes	34.0	42.0	67.0	85.0	120.0	50.0	110.0	24.0	78.0	170.0	42.0	160.0	74.0	46.0	25.0	25.0	49.0	150.0	9.3
C3-Phenan/anthracenes	25.0	31.0	35.0	51.0	64.0	30.0	42.0	15.0	48.0	90.0	25.0	75.0	37.0	27.0	22.0	16.0	23.0	77.0	8.1
C4-Phenan/anthracenes	13.0	16.0	29.0	29.0	42.0	30.0	42.0	6.5	29.0	45.0	11.0	27.0	18.0	13.0	14.0	8.5	8.5	77.0	4.7
1-Methylphenanthrene	13.0	16.0	39.0	43.0	70.0	25.0	72.0	8.5	31.0	87.0	20.0	68.0	37.0	20.0	8.5	10.0	23.0	89.0	2.4
Fluoranthene	420.0	570.0	1500.0	1500.0	2700.0	950.0	1900.0	230.0	970.0	2000.0	340.0	1400.0	490.0	460.0	170.0	290.0	320.0	4100.0	55.0
Pyrene	360.0	530.0	1300.0	1500.0	2300.0	840.0	2000.0	220.0	870.0	2000.0	320.0	1200.0	530.0	460.0	150.0	260.0	330.0	3800.0	50.0

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Appendix D-4 (*continued*)

	[PAH] (µg kg^{-1})																		
PAH	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
C1-Fluoran/pyrenes	140.0	190.0	440.0	530.0	780.0	300.0	790.0	100.0	380.0	870.0	160.0	620.0	280.0	210.0	71.0	110.0	200.0	1200.0	31.0
C2-Fluoran/pyrenes	40.0	53.0	110.0	150.0	200.0	87.0	180.0	38.0	130.0	260.0	81.0	280.0	90.0	63.0	54.0	35.0	61.0	280.0	16.0
C3-Fluoran/pyrenes	24.0	32.0	62.0	74.0	120.0	49.0	75.0	22.0	74.0	140.0	39.0	120.0	38.0	31.0	34.0	18.0	25.0	120.0	7.6
Benzo(a)anthracene	170.0	200.0	490.0	560.0	940.0	360.0	820.0	100.0	390.0	760.0	150.0	670.0	240.0	220.0	120.0	130.0	210.0	1400.0	31.0
Chrysene	210.0	280.0	590.0	670.0	1100.0	450.0	850.0	140.0	460.0	900.0	160.0	670.0	250.0	220.0	130.0	140.0	190.0	1800.0	38.0
C1-Chrysenes	71.0	83.0	180.0	220.0	350.0	150.0	260.0	57.0	180.0	340.0	75.0	320.0	120.0	93.0	57.0	54.0	95.0	540.0	18.0
C2-Chrysenes	31.0	41.0	88.0	100.0	160.0	68.0	100.0	31.0	100.0	180.0	53.0	160.0	59.0	46.0	40.0	28.0	44.0	220.0	10.0
C3-Chrysenes	11.0	15.0	36.0	41.0	71.0	30.0	42.0	15.0	54.0	87.0	29.0	62.0	21.0	20.0	26.0	9.2	15.0	83.0	4.8
C4-Chrysenes	11.0	11.0	29.0	29.0	42.0	30.0	42.0	6.2	29.0	45.0	8.1	27.0	18.0	11.0	9.3	8.5	8.5	77.0	3.3
Benzo(b)fluoranthene	280.0	330.0	600.0	830.0	1300.0	580.0	900.0	180.0	610.0	1000.0	180.0	670.0	240.0	260.0	150.0	150.0	210.0	2100.0	45.0
Benzo(k)fluoranthene	180.0	240.0	510.0	610.0	970.0	390.0	690.0	130.0	400.0	760.0	130.0	580.0	220.0	230.0	120.0	120.0	180.0	1700.0	36.0
Benzo(e)pyrene	160.0	200.0	420.0	520.0	800.0	340.0	510.0	120.0	350.0	620.0	110.0	440.0	160.0	170.0	110.0	97.0	130.0	1300.0	31.0
Benzo(a)pyrene	170.0	230.0	510.0	610.0	970.0	390.0	650.0	120.0	410.0	760.0	140.0	620.0	210.0	220.0	140.0	110.0	190.0	1600.0	35.0
Perylene	54.0	71.0	150.0	170.0	270.0	110.0	180.0	36.0	120.0	220.0	44.0	180.0	70.0	110.0	88.0	42.0	61.0	450.0	94.0
Indeno(1,2,3-cd)pyrene	110.0	150.0	350.0	380.0	550.0	230.0	320.0	86.0	210.0	390.0	74.0	380.0	100.0	110.0	110.0	61.0	91.0	850.0	26.0
Dibenz(a,h)anthracene	30.0	35.0	89.0	100.0	140.0	60.0	89.0	28.0	56.0	110.0	20.0	99.0	29.0	30.0	28.0	17.0	30.0	210.0	6.8
Benzo(g,h,i)perylene	120.0	160.0	390.0	430.0	560.0	240.0	330.0	95.0	230.0	420.0	81.0	420.0	100.0	120.0	130.0	63.0	94.0	870.0	28.0
Total PAHs	1533.2	2225.0	5612.3	5993.7	10692.0	3672.0	9100.0	967.9	3814.8	8328.0	1496.7	5744.1	2225.6	1989.6	876.7	1129.1	1499.0	15874.0	241.4

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Appendix D-5. 2011 Presque Isle Bay tributary conventional sediment chemistry data

	[Parameter] ($mg\ kg^{-1}$)																		
Parameter	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
n-Hexane Ext. Material	180	190	874	1480	1670	492	1090	412	2610	4930	565	484	252	272	192	84.4	117	1730	96.3
Nitrate/Nitrite as N	1.10	0.92	1.20	1.30	0.77	1.10	1.50	1.20	1.00	1.10	1.10	1.30	0.94	1.40	1.80	1.10	1.20	1.80	2.20
Total Nitrogen	262	463	419	430	261	353	547	801	792	5620	377	650	386	537	883	548	492	3670	831
Total Kjeldahl Nitrogen	211	356	345	346	209	270	437	627	634	4490	306	499	302	406	658	429	377	2060	646
Percent Solids (%)	81.1	77.1	82.6	80.7	80.2	76.8	80.1	78.4	80.1	79.9	81.5	76.9	78.6	75.9	74.7	78.5	76.9	56.2	78
Total Organic Carbon	4200	5140	4070	5360	8050	6400	10300	8060	9950	33800	5270	14900	5720	9120	11500	6200	6980	35800	7700
Total Phosphorus	275	276	172	263	131	276	19.4	226	340	129	6	97.3	159	141	108	16.1	93	479	216

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Appendix D-6. 2011 Presque Isle Bay tributary sediment grain size and classification data

	Percent Finer (%)																		
Particle Size (µm)	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
75000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
50000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37500	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
25000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
19000	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9500	100.0	100.0	96.3	97.1	99.1	100.0	96.4	99.2	97.0	99.1	94.9	95.8	100.0	100.0	100.0	98.9	97.5	99.0	100.0
4750	99.5	100.0	92.2	95.8	97.2	100.0	94.1	95.6	93.4	96.3	86.5	94.0	98.6	98.3	98.3	93.4	95.8	95.2	97.4
2000	97.8	99.9	79.6	88.3	86.4	99.4	88.5	86.1	79.4	86.6	66.1	88.4	96.0	91.2	86.2	80.8	89.4	82.4	92.7
850	94.6	99.0	62.0	77.0	61.4	95.4	75.5	73.0	60.0	57.4	31.3	74.2	89.3	70.5	70.1	60.2	62.1	69.4	78.6
425	86.5	93.5	42.6	62.6	39.2	74.9	53.8	49.7	43.8	29.9	10.4	53.0	61.9	45.6	52.5	37.6	25.0	60.3	56.2
250	75.2	78.9	25.2	39.0	22.2	38.3	30.4	22.5	30.0	17.4	5.4	35.9	19.4	28.0	39.8	23.7	12.9	52.6	38.6
180	56.5	55.0	9.0	17.7	8.7	11.5	10.4	7.9	11.3	12.2	3.6	29.6	8.8	21.0	33.7	18.7	10.0	47.4	32.7
150	46.6	43.2	6.0	12.4	5.9	6.8	7.2	6.2	7.4	9.9	2.9	26.5	6.4	17.8	30.5	16.5	8.9	44.5	30.4
75	13.3	9.8	2.4	5.6	2.3	3.2	4.5	4.2	2.8	5.6	2.0	19.1	4.4	11.5	22.9	12.7	6.8	37.7	24.7
37.5	4.2	4.7	2.2	2.8	2.2	2.8	3.3	3.6	2.6	3.8	1.7	9.9	2.6	6.3	14.9	7.5	5.0	21.3	16.5
23.7	3.1	3.2	1.7	1.8	1.8	2.3	2.8	2.6	2.1	2.8	1.6	7.1	2.2	5.0	11.7	5.8	3.7	17.3	13.4
13.7	2.6	2.3	1.7	1.8	1.3	1.8	2.3	2.2	1.6	2.1	1.0	5.3	2.2	3.2	9.2	4.5	3.3	13.4	9.7
9.4	2.0	1.8	1.7	1.3	0.8	1.8	1.8	1.7	1.6	1.8	1.0	4.3	1.4	2.4	7.9	3.7	2.8	10.4	8.1
6.9	2.0	1.8	1.7	0.8	0.8	0.8	1.3	0.8	1.2	1.5	0.4	2.9	0.5	2.4	6.5	2.8	2.0	8.4	6.6
3.3	1.4	1.3	0.7	0.8	0.8	0.8	0.8	0.7	1.2	1.1	0.4	1.9	0.5	1.4	4.6	1.9	1.5	5.3	3.5
1.4	0.9	0.8	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.4	0.5	0.1	0.5	3.3	1.4	1.4	3.1	2.8

	Percent of Sample (%)																		
Soil Class	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	GR0	GR1	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8
Gravel	0.5	0.0	7.8	4.2	2.8	0.0	5.9	4.4	6.6	3.7	13.5	6.0	1.4	1.7	1.7	6.6	4.2	4.8	2.6
Sand	86.2	90.2	89.8	90.2	95.0	96.8	89.6	91.4	90.6	90.7	84.9	74.9	94.2	86.8	75.4	80.7	89.0	57.5	72.7
Coarse sand	1.7	0.1	12.6	7.5	10.8	0.6	5.6	9.5	14.0	9.7	20.4	5.6	2.6	7.1	12.1	12.6	6.4	12.8	4.7
Medium sand	11.3	6.4	37.0	25.7	47.2	24.5	34.7	36.4	35.6	56.7	55.7	35.4	34.1	45.6	33.7	43.2	64.4	22.1	36.5
Fine sand	73.2	83.7	40.2	57.0	37.0	71.7	49.3	45.5	41.0	24.3	8.8	33.9	57.5	34.1	29.6	24.9	18.2	22.6	31.5
Silt	11.3	8.0	0.7	4.8	1.3	2.4	3.1	3.5	1.6	4.1	1.2	16.2	3.9	9.2	16.4	9.9	4.9	29.3	18.1
Clay	2.0	1.8	1.7	0.8	0.8	0.8	1.3	0.8	1.2	1.5	0.4	2.9	0.5	2.3	6.5	2.8	2.0	8.4	6.6

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