An evaluation of water quality conditions in the tributaries of Presque Isle Bay: 2012

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Great Lakes RESTORATION

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1.0 Abstract

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 of 26.22 square miles. Major tributaries of the bay include, from west to east, Scott Run, Cascade Creek, Mill Creek, and its tributary Garrison Run. In 1991, the bay was listed as the 43rd and final Area of Concern under the Great Lakes Water Quality Agreement due the presence of fish tumors and restrictions on dredging due to contaminated sediments. In 2007, the restrictions on dredging beneficial-use impairment was delisted for the bay partially due to improving sediment quality. As a result of the delisting, the *Presque Isle Bay Watershed Restoration, Protection, and Monitoring 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. The objective of this study was to evaluate water quality at 19 sites throughout the Presque Isle Bay watershed, including 16 historical sites and three sites at the mouths of Scott Run, Mill Creek, and Garrison Run. Concentrations of the water quality parameters were evaluated against Pennsylvania Chapter 93 Water Quality Standards, EPA Water Quality Standards, and the literature to determine if conditions are sufficient to support and protect aquatic and human health. The results of the analysis suggest that water quality in the watershed should support and protect aquatic life; nutrients concentrations should not result in eutrophication; and while streams within the watershed may not be safe for recreational uses such as swimming as a result of elevated *E. coli* levels, the source of *E. coli* contamination is likely non-human. Future investigations should consider evaluating water chemistry seasonally and under varying flows to provide a better understanding of water quality conditions in the watershed.

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 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 United States Environmental Protection Agency (EPA) 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* 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 2011-12.

The objective of this study was to evaluate the water quality conditions at the 16 sites assessed by Diz and Johnson (2002) and three additional sites at the mouths of Scott Run, Mill Creek, and Garrison Run. Results of the water quality conditions were evaluated against Pennsylvania Chapter 93 Water Quality Standards, EPA Recreation Water Quality Standards, and the literature.

3.0 Methodology

3.1 Sampling Sites and Sample Collection

In June 2012, water 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). The latitude and longitude were recorded at each site using a Garmin GPSMAP® 60CSX handheld GPS unit. The water quality parameters assessed were consistent with DEP (2007). Dissolved oxygen, pH, specific conductance, and temperature were measured in the field using a Quanta® Hydrolab®. *Escherichia coli* (*E. coli*), mercury, aluminum, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, zinc, ammonia, chemical oxygen demand (COD), hardness, oil and grease, turbidity, nitrate, nitrite, chloride, sulfate, orthophosphate, alkalinity, total solids, total dissolved solids (TDS), total suspended solids (TSS), settable solids, 5-day biochemical oxygen demand (BOD5), total organic carbon (TOC), total nitrogen, total kjeldahl nitrogen (TKN), total phosphorus, and phosphorus as phosphate (P as PO_4) were measured in the laboratory.

Water samples for laboratory analyses were collected in bottles with appropriate fixatives in accordance with the Test America, Inc. protocol (***Table 2***). All sample containers without fixatives were triple-rinsed with site water prior to sample collection. All samples without fixatives were collected from mid-channel and mid-depth. The dissolved phosphorus samples were field-filtered through a 0.45 µm Whatman® cellulose membrane filter using a Nalgene® hand-operated vacuum pump. Water for the sample containers with fixatives was collected mid-channel and mid-depth using a 4.0 L stainless steel bucket. The bucket was triple-rinsed with site water prior to sample collection. The water was then transferred from the bucket to the appropriate sample containers. All samples were immediately placed on ice to lower the temperature to 4°C and transported 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. The samples were wrapped in bubble wrap and packed (in an upright position) in 48-liter coolers with ice. The sample chain-of-custody forms were placed in a Ziploc® bag and attached to the inside of the cooler lid. The coolers were sealed with duct tape and shipped overnight to Test America, Inc. in Pittsburgh, Pennsylvania. All *E. coli* samples were submitted to the Regional Science Consortium for analysis within two-hours of collection.

3.3 Sample Analysis

Mercury, aluminum, cadmium, calcium, chromium, copper, iron, lead, magnesium, manganese, nickel, zinc, ammonia, COD, hardness, oil and grease, turbidity, nitrate, nitrite, chloride, sulfate, orthophosphate, alkalinity, total solids, total dissolved solids, total suspended solids, settable solids, BOD5, TOC, total nitrogen, TKN, total phosphorus, and phosphorus as phosphate analyses were performed by Test America, Inc. The analytical methods used by Test America, Inc. are those currently accepted and approved by the EPA, including Standard Methods (SM), EPA Methods (EPA), and SW846 Methods (SW). *E. coli* analysis was performed by the Regional Science Consortium laboratory. The Regional Science Consortium used EPA Method 1603 to evaluate *E. coli* in water samples (U.S. EPA 2002).

3.4 Data Analysis

The temperature, dissolved oxygen, pH, mercury, aluminum, cadmium, chromium, copper, iron, lead, manganese, nickel, zinc, ammonia, nitrate/nitrite, chloride, sulfate, alkalinity, and total dissolved solids results were compared to Pennsylvania Chapter 93 water quality standards (PA 25 § 93). *E. coli*, specific conductance, turbidity, TOC, total nitrogen, TKN, total phosphorus, and phosphorus as phosphate, and total suspended solids were compared to U.S. EPA standards (EPA 1976; Mills et al. 1985; EPA 1997; EPA 2000; EPA 2010; EPA 2011). Calcium, magnesium, COD, BOD5, oil and grease, and orthophosphate results were evaluated against concentrations published in the literature (***Table 3***). To reflect the highest possible concentration, non-detectable (ND) concentrations were presented as the method detection limit (MDL).

4.0 Results

The concentrations presented herein represent warm, low-flow conditions for the tributaries and only provide a snapshot of the actual conditions in the watershed. All 2012 water chemistry data are presented in ***Appendix D***.

4.1 Pennsylvania Chapter 93 Water Quality Standards

Stream temperatures ranged from 59.00°F (CC3) to 69.96°F (GR0) (***Figure 1***). All sites met the temperature standards for maintaining warm water fishes (WWF) and trout stocking fishery (TSF); however, only site CC3 met the standards for sustaining cold water fishes (CWF). Dissolved oxygen (DO) concentrations ranged from 5.90 mg L^{-1} (MC7) to 11.71 mg L^{-1} (MC0) (***Figure 2***). All sites met the DO standard for maintaining CWF, WWF, and TSF. pH values ranged from 7.72 (CC6) to 8.54 (MC0) (***Figure 3***). All sites met the pH standard for maintaining CWF, WWF, TSF, and migratory fishes (MF).

All sites had ND concentrations of mercury (***Figure 4***). The MDL for mercury was 0.031 µg L^{-1}. None of the sites had mercury concentrations exceed fish and aquatic life criteria. Aluminum concentrations ranged from 26.0 µg L^{-1} (SR1) to 460.0 µg L^{-1} (MC1) (***Figure 5***). None of the sites had aluminum concentrations exceed fish and aquatic life criteria. Site MC4 had a cadmium concentration of 0.16 µg L^{-1}; all other sites had ND concentrations of cadmium (***Figure 6***). The MDL for cadmium was 0.15 µg L^{-1}. None of the sites had cadmium concentrations exceed fish and aquatic life criteria. Chromium concentrations ranged from 0.53 µg L^{-1} (CC2) to 1.10 µg L^{-1} (GR1); 14 sites had ND concentrations of chromium (***Figure 7***). The MDL for chromium was 0.51 µg L^{-1}. None of the sites had chromium concentrations exceed fish and aquatic life criteria. Copper concentrations ranged from 2.9 µg L^{-1} (GR1) to 4.2 µg L^{-1} (GR0); 15 sites had ND concentrations of copper (***Figure 8***). The MDL for copper was 2.5 µg L^{-1}. None of the sites had copper concentrations exceed fish and aquatic life criteria.

Iron concentrations ranged from 81 µg L^{-1} (MC5 and MC6) to 2,000 µg L^{-1} (CC5) (***Figure 9***). Sites CC2, CC3, CC4, CC5, CC6, MC1, MC4, MC7, MC8, GR0, and GR1 failed to meet the fish and aquatic life criteria for iron. Lead concentrations ranged from 1.5 µg L^{-1} (MC1) to 4.2 µg L^{-1} (GR0); 16 sites had

ND concentrations of lead (***Figure 10***). The MDL for lead was 1.3 µg L^{-1}. None of the sites had lead concentrations exceed fish and aquatic life criteria. Manganese concentrations ranged from 9.3 µg L^{-1} (MC5) to 330.0 µg L^{-1} (GR0) (***Figure 11***). None of the sites had manganese concentrations exceed fish and aquatic life criteria. Nickel concentrations ranged from 0.99 µg L^{-1} (CC4) to 4.10 µg L^{-1} (GR0); nine sites had ND concentrations of nickel (***Figure 12***). None of the sites had nickel concentrations exceed fish and aquatic life criteria. Zinc concentrations ranged from 2.1 µg L^{-1} (MC6) to 91.0 µg L^{-1} (CC6) (***Figure 13***). None of the sites had zinc concentrations exceed fish and aquatic lifer criteria.

Ammonia concentrations ranged from 61.0 µg L^{-1} (MC8) to 360.0 µg L^{-1} (CC6) (***Figure 14***). None of the sites had ammonia concentrations exceed fish and aquatic life criteria. Nitrate and nitrite concentrations ranged from 0.36 mg L^{-1} to 1.60 mg L^{-1} (CC4, CC6, and MC8) (***Figure 15***). None of the sites had nitrate and nitrite concentrations exceed fish and aquatic life criteria. Chloride concentrations ranged from 46.0 mg L^{-1} to 330.0 mg L^{-1} (***Figure 16***). Sites CC4 and CC5 failed to meet the fish and aquatic life criteria for chloride. Sulfate concentrations ranged from 25.0 mg L^{-1} (MC3 and MC6) to 120.0 mg L^{-1} (GR1) (***Figure 17***). None of the sites had sulfate concentrations exceed fish and aquatic life criteria. Alkalinity ranged from 140.0 mg L^{-1} (MC1, MC4, MC5, and MC6) to 260.0 mg L^{-1} (CC5 and CC6) (***Figure 18***). None of the sites had alkalinity exceed fish and aquatic life criteria. Total dissolved solids (TDS) concentrations ranged from 230.0 mg L^{-1} (MC7) to 830.0 mg L^{-1} (CC5) (***Figure 19***). Sites CC5 and GR1 failed to meet the fish and aquatic life criteria for TDS.

4.2 EPA Standards

E. coli counts ranged from 250 *E. coli*/100 mL (CC5) to 2,620 *E. coli*/100 mL (MC 0) (***Figure 20***). All sites had *E. coli* concentrations exceed the EPA (2011) *E. coli* standard for recreational water use. Specific conductance ranged from 245 µS/cm (MC4) to 1,650 µS/cm (CC5) (***Figure 21***). The specific conductance at site CC5 exceeded values typically observed in U.S. rivers (EPA 1997). The specific conductance at sites SR0, SR1, CC1, CC2, CC3, CC4, CC5, CC6, MC0, MC1, MC2, MC3, MC5, MC6, MC8, GR0, and GR1 exceeded values observed in streams supporting healthy fisheries (EPA 1997). Turbidity ranged from 0.84 NTU (MC5) to 12.0 NTU (MC4) (***Figure 22***). None of the sites had turbidity exceed values necessary to protect all freshwater uses (EPA 1988); however, sites SR0, CC2, CC3, CC4, CC5, CC6, MC0, MC1, MC3, MC4, MC7, MC8, GR0, and GR1 had turbidity exceed values necessary to protect against eutrophication (EPA 2000). Total organic carbon (TOC) concentrations ranged from 1.8 mg L^{-1} (CC3) to 6.4 mg L^{-1} (MC4) (***Figure 23***). Sites MC0, MC1, MC3, MC4, MC7, MC8, GR0, and GR1 had TOC concentrations exceed values necessary to prevent trihalomethane formation in raw drinking water subject to chlorination (EPA 2010). Total suspended solid (TSS) concentrations ranged from 2.4 mg L^{-1} (SR0 and MC2) to 30.0 mg L^{-1} (MC7) (***Figure 24***). Sites CC5, MC7, and MC8 had TSS concentrations that could potentially impair aquatic habitats (Mills *et al.* 1985).

Total nitrogen concentrations ranged from 0.36 mg L^{-1} (MC4) to 3.30 mg/L^{-1} (MC7) (***Figure 25***). Sites SR0, CC1, CC2, CC3, CC4, CC5, CC6, MC0, MC1, MC2, MC3, MC5, MC6, MC7, MC8, GR0, and GR1 had total nitrogen concentrations exceed values necessary to protect against eutrophication (EPA 2000). All sites had ND concentrations of TKN. The MDL for TKN was 2.50 mg L^{-1}. The TKN concentrations were not evaluated against the criteria for protecting against eutrophication (EPA 2000) because the criteria (0.24 mg L^{-1}) is below the MDL. All sites had ND concentrations of total phosphorus (***Figure 26***). The MDL for total phosphorus was 0.005 mg L^{-1}. All sites had total phosphorus concentrations below the criteria for protecting against eutrophication (EPA 2000). All sites had ND phosphorus as phosphate (P as PO_4) concentrations (***Figure 27***). The MDL for P as PO_4 is 0.015 mg L^{-1}. All sites had P as PO_4 concentrations below the criteria for preventing accelerated eutrophication (EPA 1976).

4.3 Concentrations Observed in Freshwater Systems

Calcium concentrations ranged from 46.0 mg L^{-1} (MC6) to 120.0 mg L^{-1} (GR0 and GR1) (***Figure 28***). Sites CC5, GR0, and GR1 had calcium concentrations outside of the typical range observed in freshwater; however, all sites met the minimum calcium criteria necessary to support plants and animals (Lehigh University). Magnesium concentrations ranged from 8.6 mg L^{-1} (MC6) to 21.0 mg L^{-1} (GR0 and GR1) (***Figure 29***). All sites had magnesium concentrations within the typical range observed in freshwater systems (Lehigh University). Chemical oxygen demand (COD) ranged from 15.0 mg L-1 (MC6) to 51.0 mg L-1 (MC0) (***Figure 30***). Sites SR0, SR1, CC1, CC2, CC3, CC4, CC5, CC6, MC0, MC1, MC4, GR0, and GR1 had COD exceed 20.0 mg L^{-1}, which indicates potential pollution (NOAA NERRS). Five-day biochemical oxygen demand (BOD5) ranged from 1.8 mg L^{-1} (MC2) to 7.6 mg L^{-1} (MC0); 14 sites had ND BOD5 (***Figure 31***). The MDL for BOD5 was 0.79 mg L^{-1}. Site MC0 had BOD5 between 5.0 and 20.0 mg L^{-1}, which indicates the presence of organic pollution; however, none of the sites exceeded the BOD5 pollution threshold of 20.0 mg L^{-1} (Diz and Johnson 2002). Site MC1 had an oil and grease concentration of 3.3 mg L^{-1}; all other sites had ND concentrations of oil and grease (***Figure 32***). The MDL for oil and grease was 1.4 mg L^{-1}. None of the sites exceeded the oil and grease pollution threshold of 10.0 mg L^{-1} (Wyoming Chapter 1 Water Quality Standards). All sites had ND concentrations of orthophosphate. The MDL for orthophosphate was 0.077 mg L^{-1}. The orthophosphate concentrations were not evaluated against criteria for preventing long-term eutrophication (Dunne and Leopold 1978) because the criteria (0.05 mg L^{-1}) was below the MDL.

5.0 Discussion

Water quality standards serve as the foundation for the water-quality based approach to pollution control. The purpose of water quality standards is to ensure that all surface waters have appropriately designated uses and criteria to maintain water quality at a level necessary to protect those uses consistent with the Clean Water Act. The water quality standards take into consideration the use and value of the water body for public water supply, for propagation of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes.

Pennsylvania's Chapter 93 aquatic life water quality criteria were developed and adopted by DEP based on approved methodologies and the best scientific information currently available. The numeric values represent concentrations, levels, or surface water conditions that need to be maintained or attained to protect existing and designated uses such as aquatic life and fish (PA 25 § 93.1). Temperature, DO, and pH in the Presque Isle Bay watershed were sufficient to maintain and support breeding populations of fishes indigenous to warm water habitat, and maintain stocked trout. DO and pH were also sufficient to maintain and support breeding populations of fishes indigenous to cold-water habitat, including the family Salmonidae. Concentrations of mercury, aluminum, cadmium, chromium, copper, lead, nickel, zinc, ammonia, nitrate/nitrite, chloride, sulfate, and alkalinity met acute fish and aquatic life criteria at all 19 sites. Based on these results, water quality in the watershed should support and protect aquatic life.

Nutrients are essential to the health and diversity of surface waters. However, in excessive amounts, nutrients can cause hyper-eutrophication, which results in the overgrowth of plant life and decline of the biological community. The major sources of nutrients to streams include precipitation, dissolution of natural minerals from soil, fertilizer application, and effluent from sewage-treatment plants (Mueller and Helsel 1996). EPA (2000) provides recommended criteria for causal variables (total phosphorus and total nitrogen), and response variables (turbidity and chlorophyll a) for rivers and streams in Nutrient Ecoregion VII, which includes the Presque Isle Bay watershed. The ecoregional nutrient criteria are intended to address cultural eutrophication and are empirically derived to represent conditions of surface waters that are minimally impacted by human activities and protective of aquatic life and recreational uses (EPA 2000).

In the Presque Isle Bay watershed, total nitrogen concentrations exceeded the threshold (0.54 mg L^{-1}) necessary to protect against eutrophication at 17 of 19 sites. However, total phosphorus concentrations were non-detectable at all the sites and thus, eutrophication thresholds were not exceeded. In freshwater systems, phosphorus is the limiting nutrient for plant growth. Turbidity measures suspended organic and inorganic matter in the water column, and although turbidity is not commonly used as an index of eutrophication, it can increase in streams with increasing algal biomass due to nutrient enrichment (Buck *et al.* 2000). Turbidity measurements exceeded the threshold (1.70 NTU) indicative of eutrophication at 14 of 19 sites. While the total nitrogen concentrations and turbidity were elevated in streams, a definitive determination of trophic status cannot be made without chlorophyll measurements. Dodds *et al.* (1998) classified streams into trophic categories using total nitrogen, total phosphorus, and chlorophyll. Dodds *et al.* (1998) consider a stream eutrophic when total nitrogen concentrations exceed 1.5 mg L^{-1}, total phosphorus concentrations exceed 0.075 mg L^{-1}, and chlorophyll concentrations exceed 0.03 mg L^{-1}. Based on Dodd's criteria, total nitrogen and phosphorus concentrations should not lead to eutrophication in the Presque Isle Bay watershed.

Contaminants in the water do not only affect aquatic life; they also pose a risk to human health. EPA developed human health water quality criteria by assessing the relationship between pollutants and their effect on human health. The criteria represent the highest concentration of a pollutant in water that is not expected to pose a significant risk to human health. EPA (2011) provides recommended recreational (i.e. bathing, swimming, or surfing) water quality criteria for states. EPA recommends the use of *E. coli* as an indicator as it is a good predictor of gastrointestinal illness in fresh waters. *E. coli* is bacteria found in the digestive tracts and feces of humans, wildlife, and domestic animals (Whitlock *et al.* 2002). Sources of *E. coli* pollution in urban streams include stormwater runoff, failing septic systems, direct deposition of animal feces, wastewater treatment plants, illicit discharges, and storm drains (Petersen *et al.* 2005).

All 19 sites in the Presque Isle Bay watershed had *E. coli* counts exceed the recreational use standard of 235 *E. coli*/100 mL. Stein and Ackerman (2007) identified storm drains as the primary source of bacteria in urban streams in Los Angeles, California, during dry weather. Contributors of *E. coli* to storm sewers in urban areas include illicit discharges, and feces from urban wildlife and domestic pets (Murray *et al.* 2001). In the early 1990s, nearly $100 million was spent to eliminate combined sewer overflows from the Erie Wastewater Treatment, which services the Presque Isle Bay watershed. As part of the efforts, the sanitary sewer system and storm sewer system were separated; therefore, illicit discharges should not significantly contribute to *E. coli* levels in the streams. Ram *et al.* (2007) proposed that if elevated bacterial levels remain after the elimination of illicit connections, then identification of pet and wildlife sources are critical to decreasing bacterial loads. Ram *et al.* (2007) identified feces from pets and raccoons as important contributors to *E. coli* levels in urban storm sewers that discharge into a tributary of the Huron River in Ann Arbor, Michigan. Simmons *et al.* (2000) found that non-human species (raccoon, canine, feline, seagull, Canada goose, opossum, Norway rat, red fox, flying squirrel, and gray squirrel) were the primary sources of *E. coli* in an urban stream in northern Virginia. While the streams in the Presque Isle Bay watershed may not be safe for recreational uses such as swimming as a result of elevated *E. coli* levels, the source of *E. coli* contamination is likely non-human.

The concentrations presented herein are representative of low-flow, dry-weather conditions for the tributaries and only provide a snapshot of the actual conditions in the watershed. Future investigations should consider evaluating water chemistry seasonally and under varying flows to provide a better understanding of water quality conditions in the watershed. In conclusion, many parameters met water quality criteria in the watershed and should support aquatic life; nutrient concentrations in the streams should not result in eutrophication; and *E. coli* levels suggest that the streams may not be safe for recreational uses, but the sources of *E. coli* are likely non-human.

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APPENDIX A: FIGURES

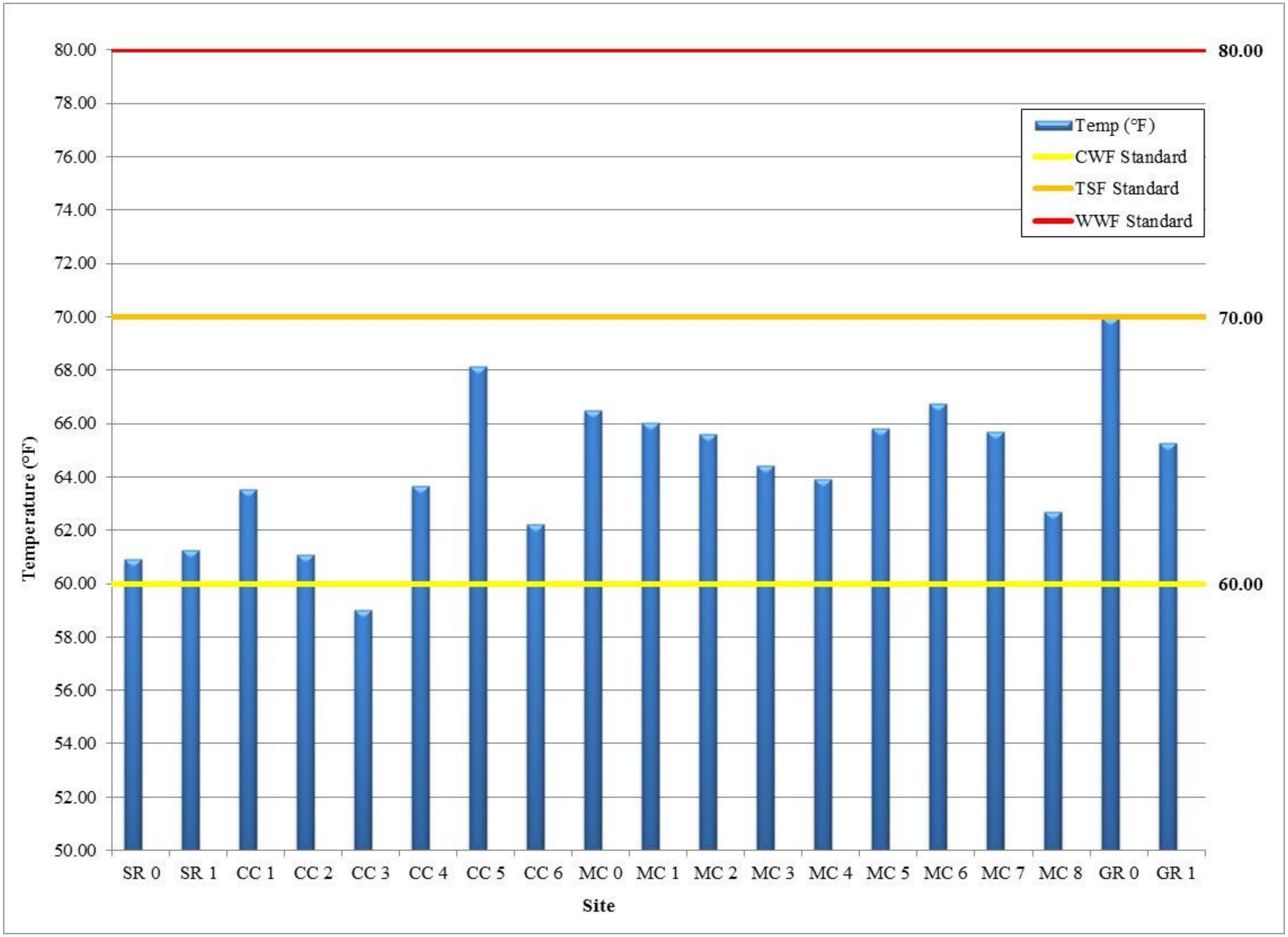

Figure 1. Temperatures in the Presque Isle Bay watershed (2012)

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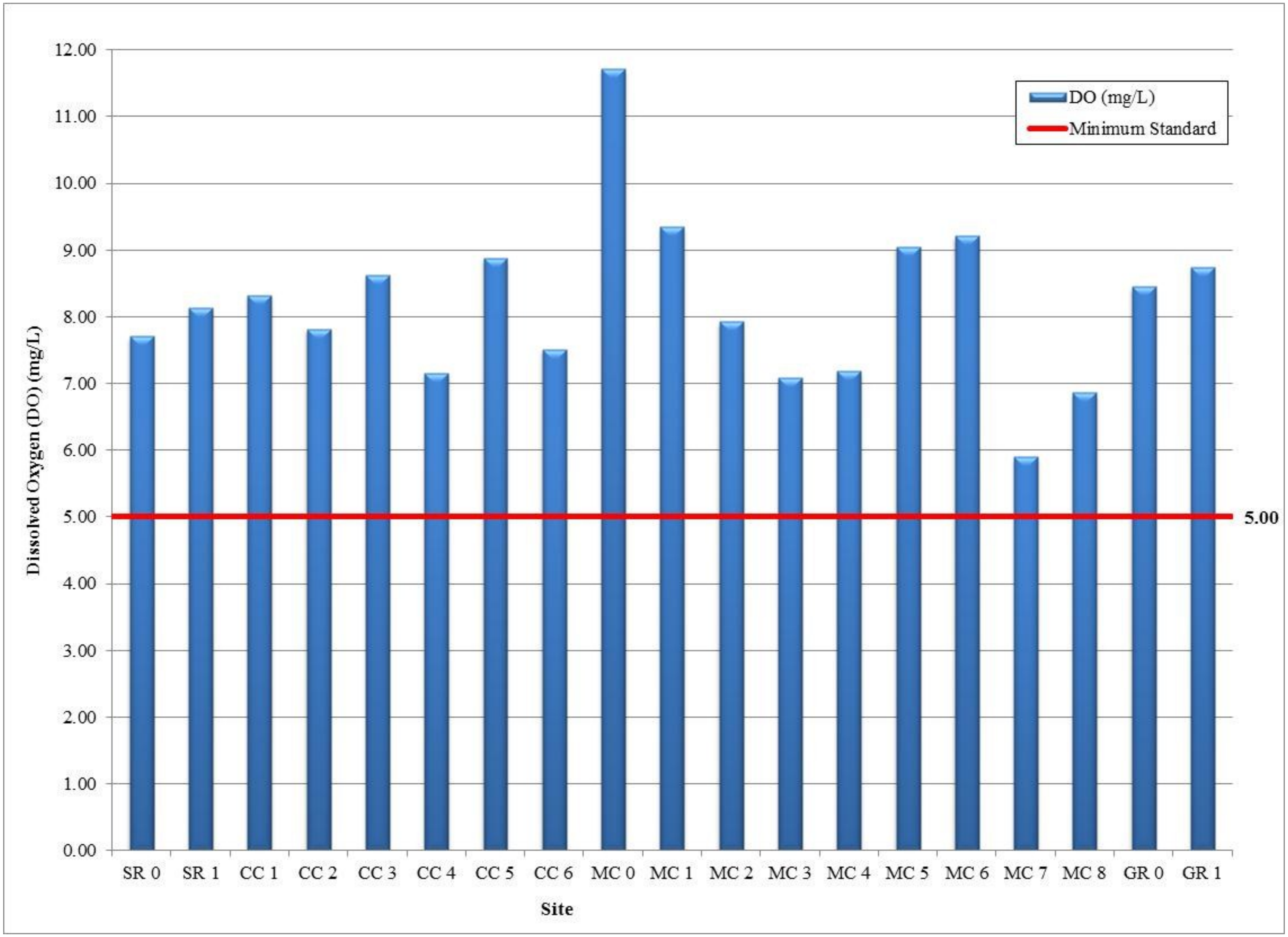

Figure 2. Dissolved oxygen concentrations in the Presque Isle Bay watershed (2012)

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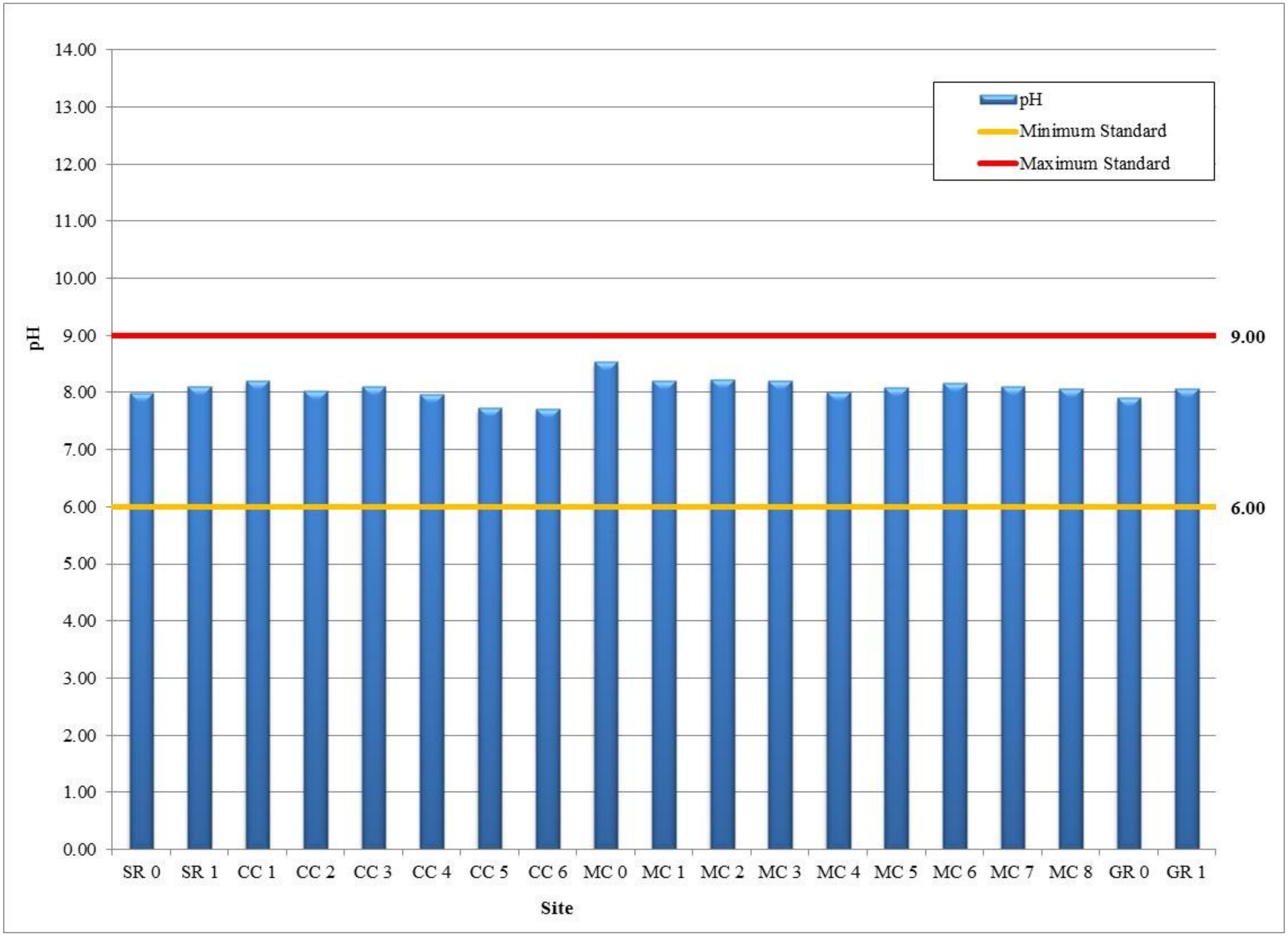

Figure 3. pH values in the Presque Isle Bay watershed (2012)

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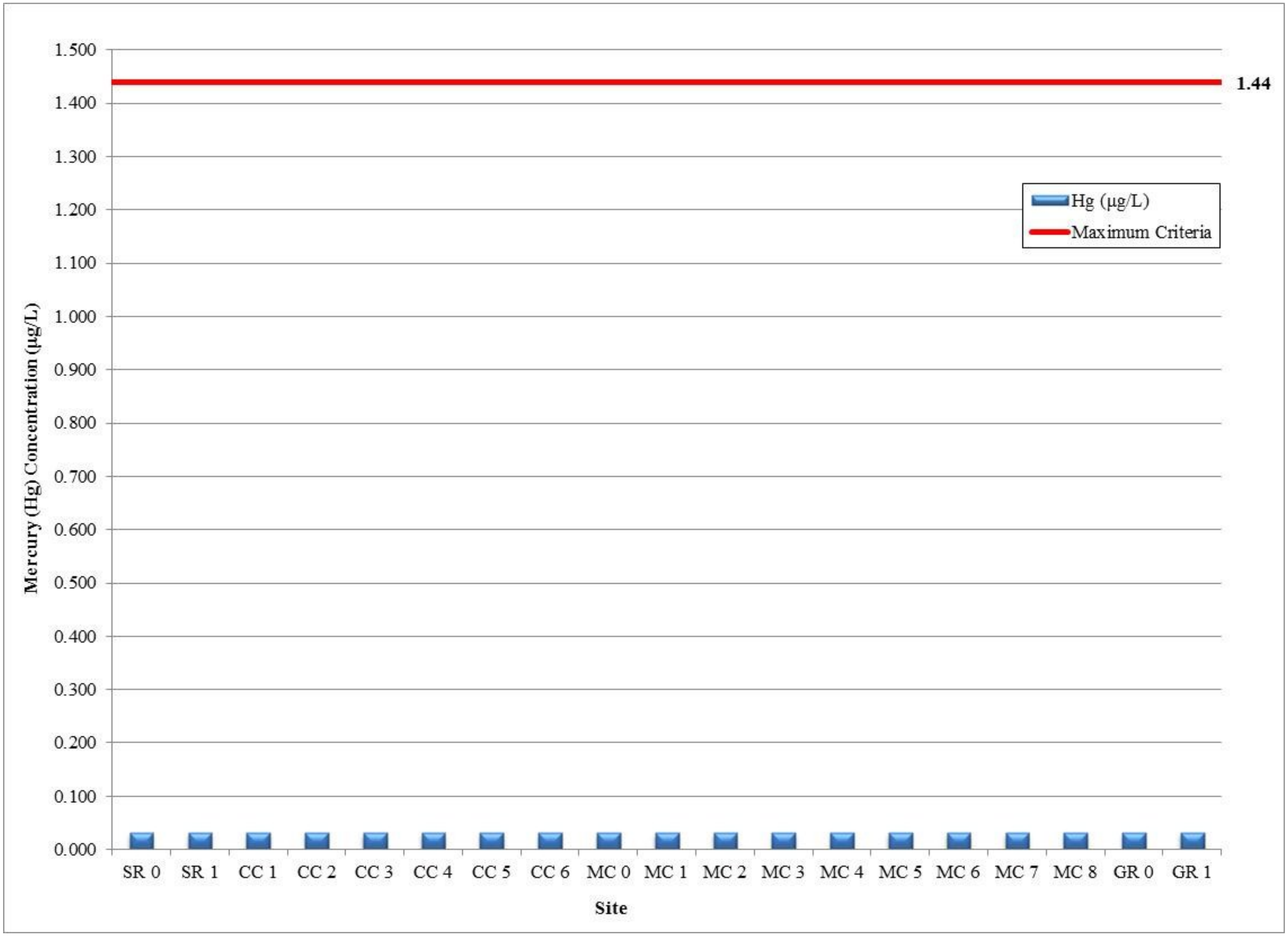

Figure 4. Mercury concentrations in the Presque Isle Bay watershed (2012)

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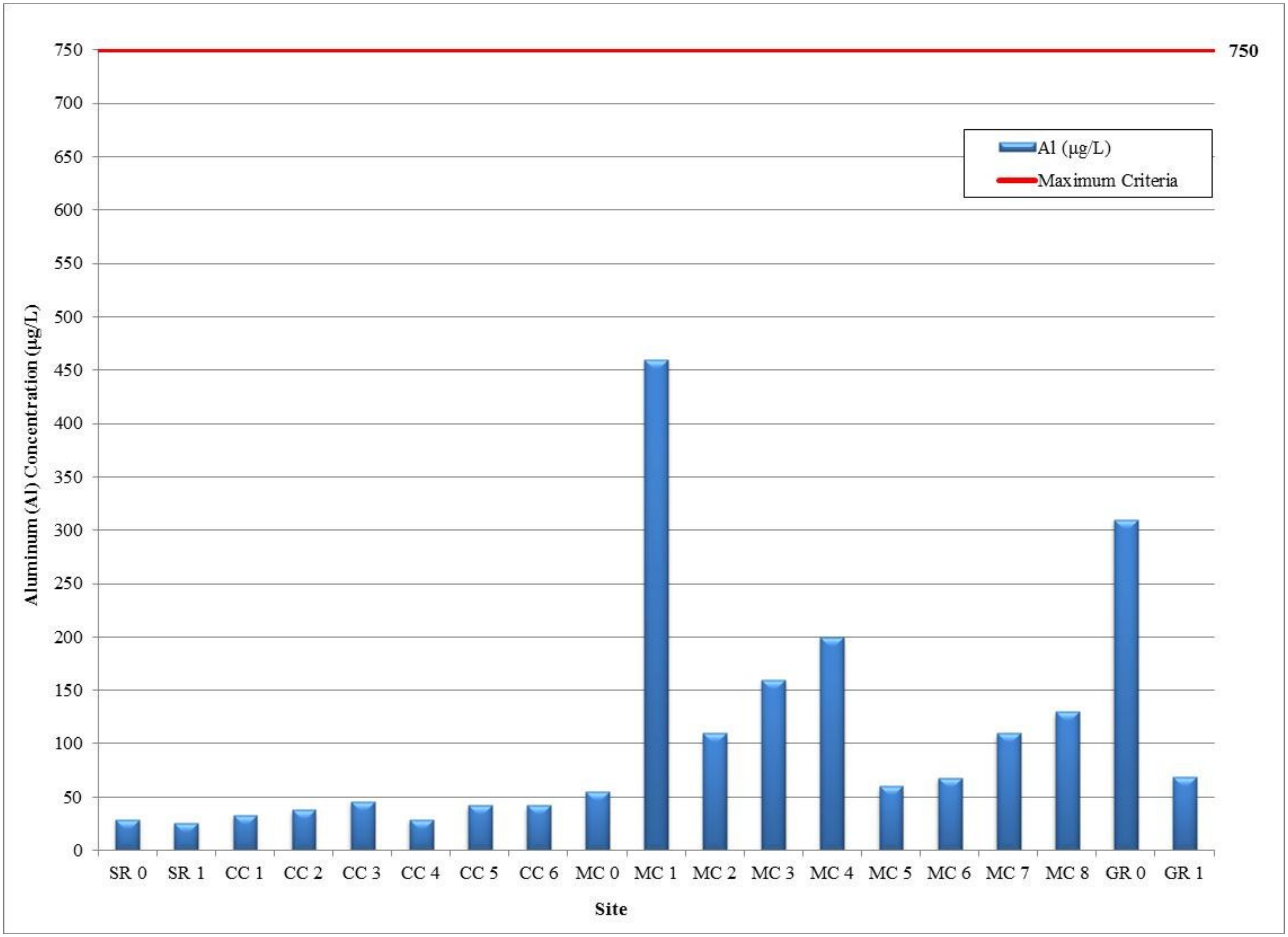

Figure 5. Aluminum concentrations in the Presque Isle Bay watershed (2012)

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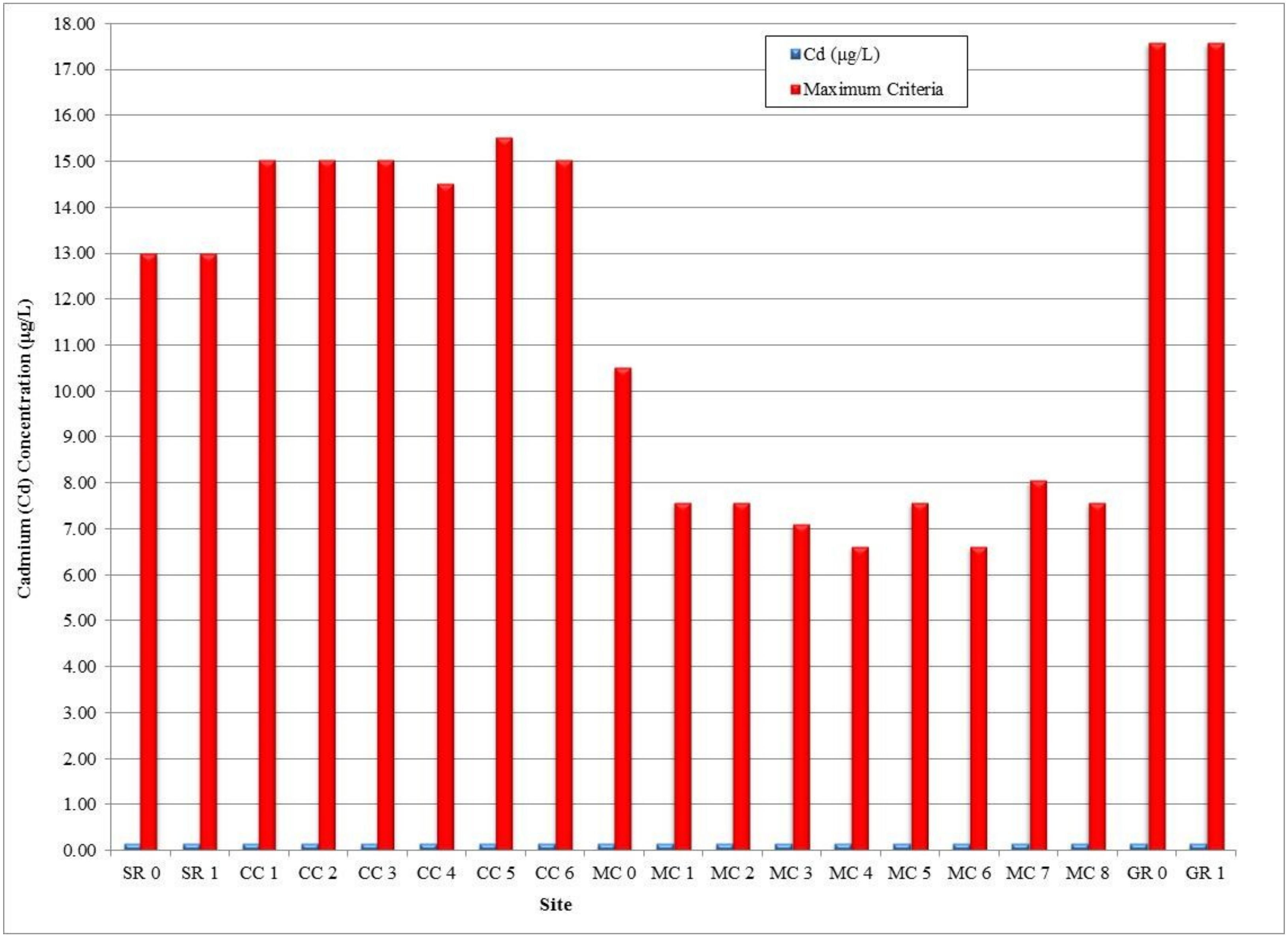

Figure 6. Cadmium concentrations in the Presque Isle Bay watershed (2012)

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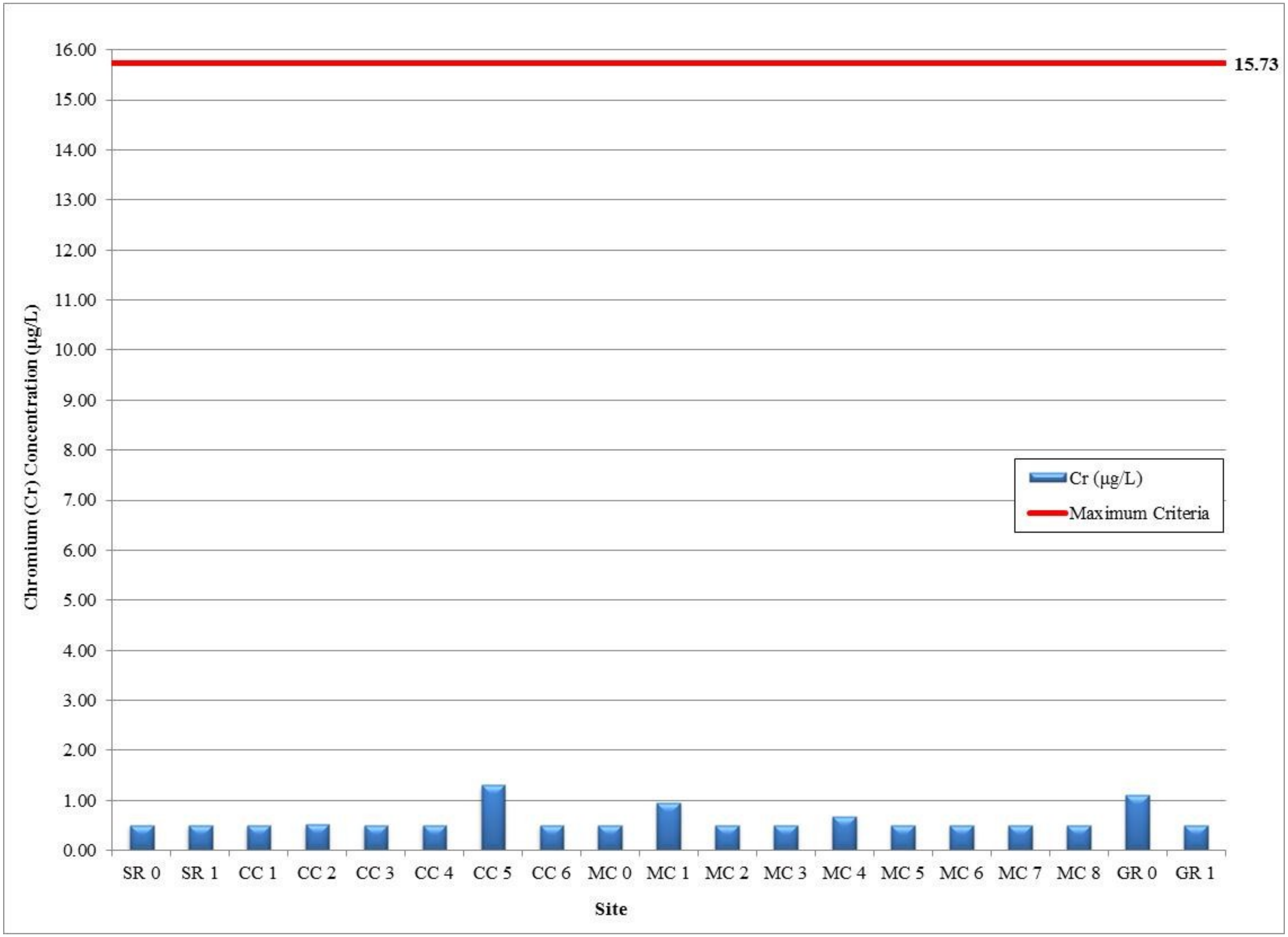

Figure 7. Chromium concentrations in the Presque Isle Bay watershed (2012)

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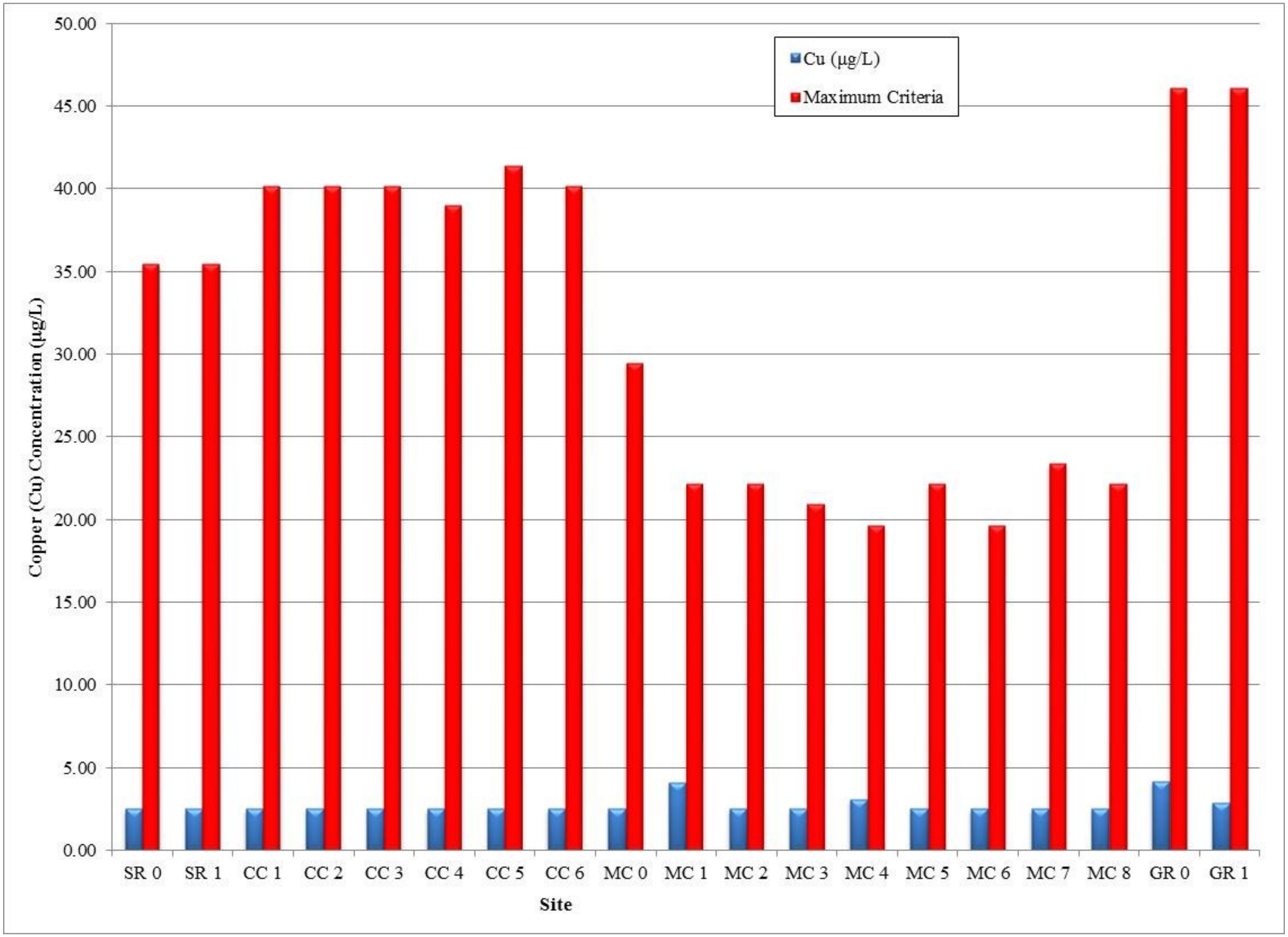

Figure 8. Copper concentrations in the Presque Isle Bay watershed (2012)

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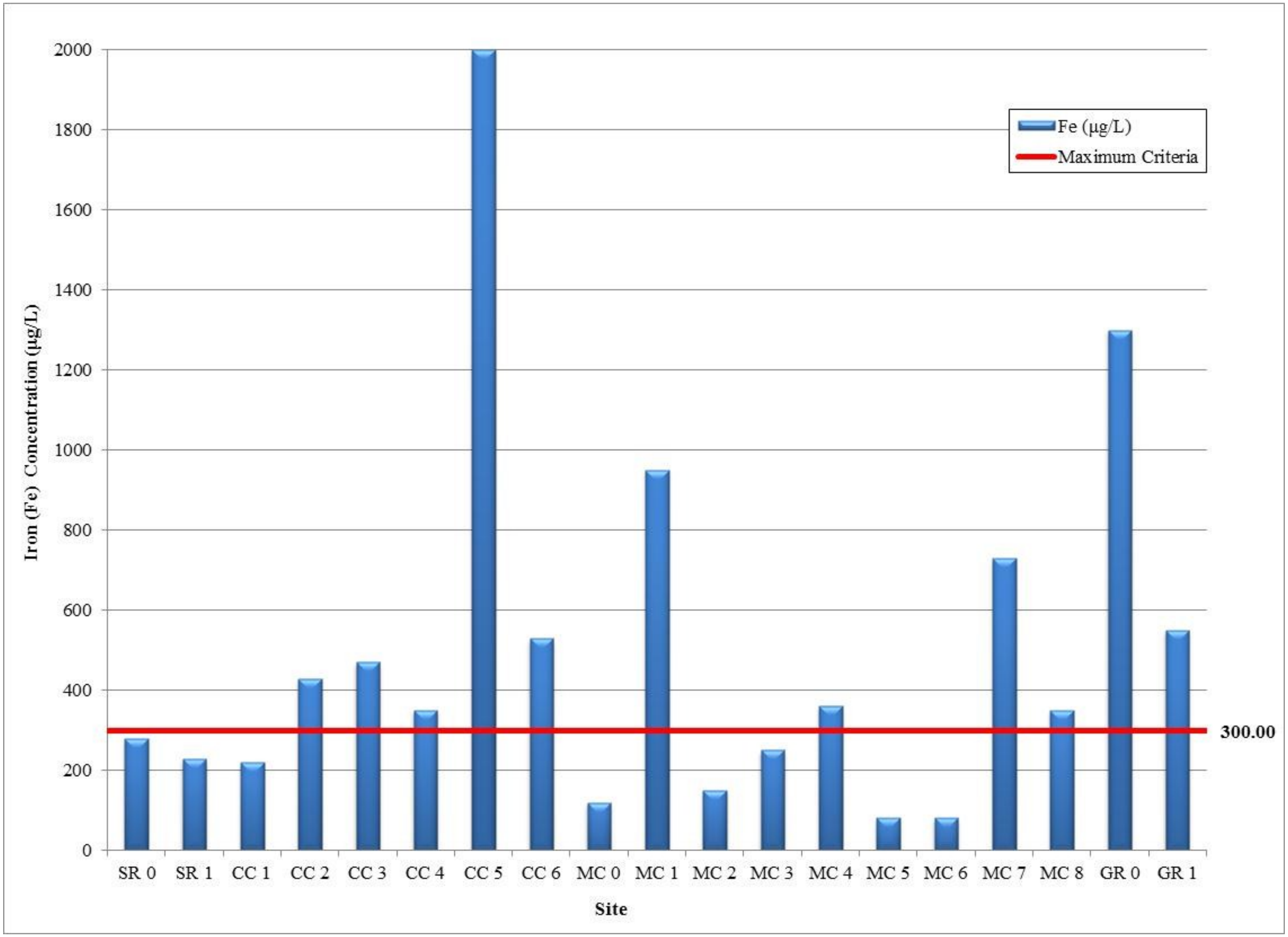

Figure 9. Iron concentrations in the Presque Isle Bay watershed (2012)

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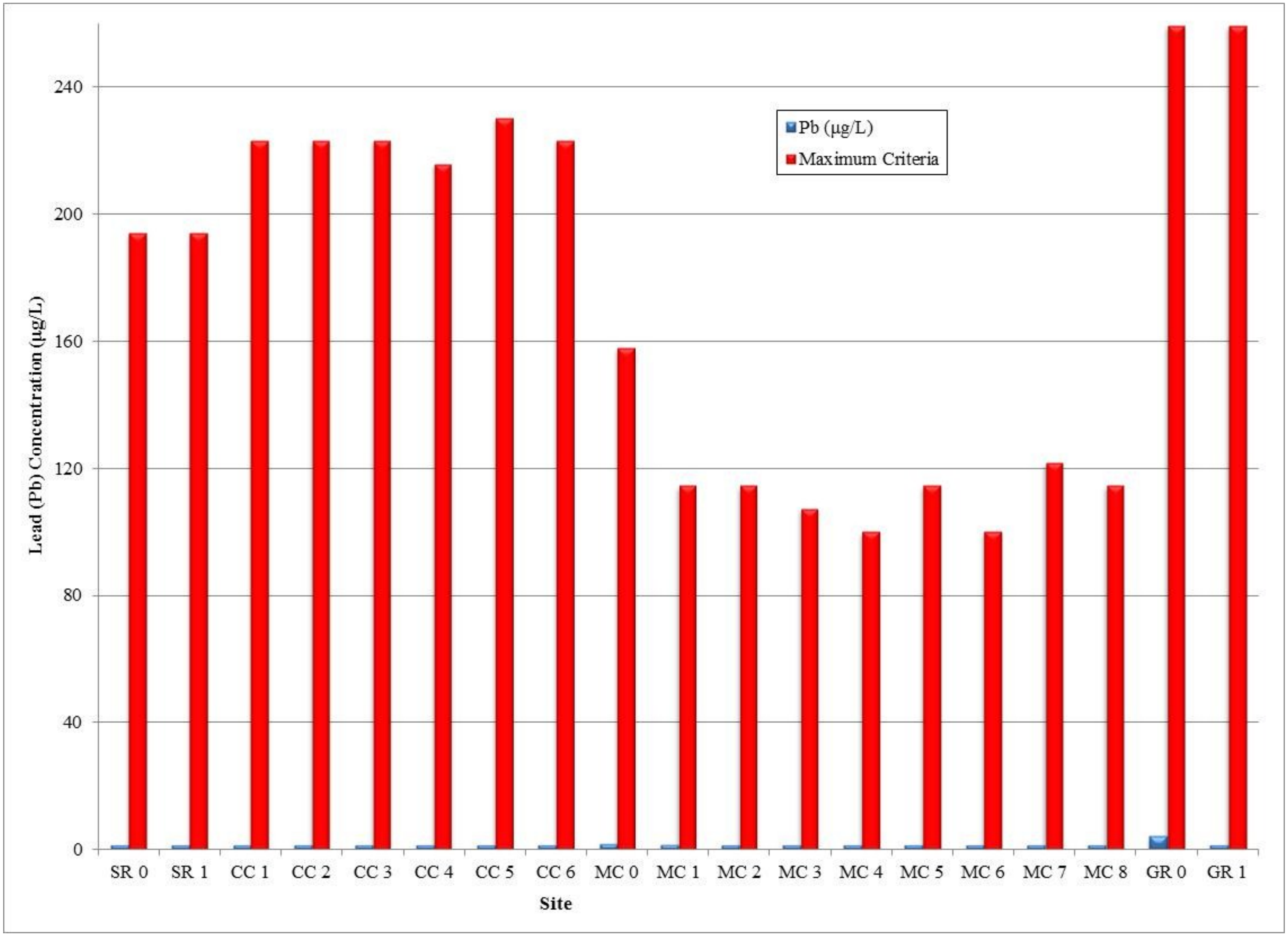

Figure 10. Lead concentrations in the Presque Isle Bay watershed (2012)

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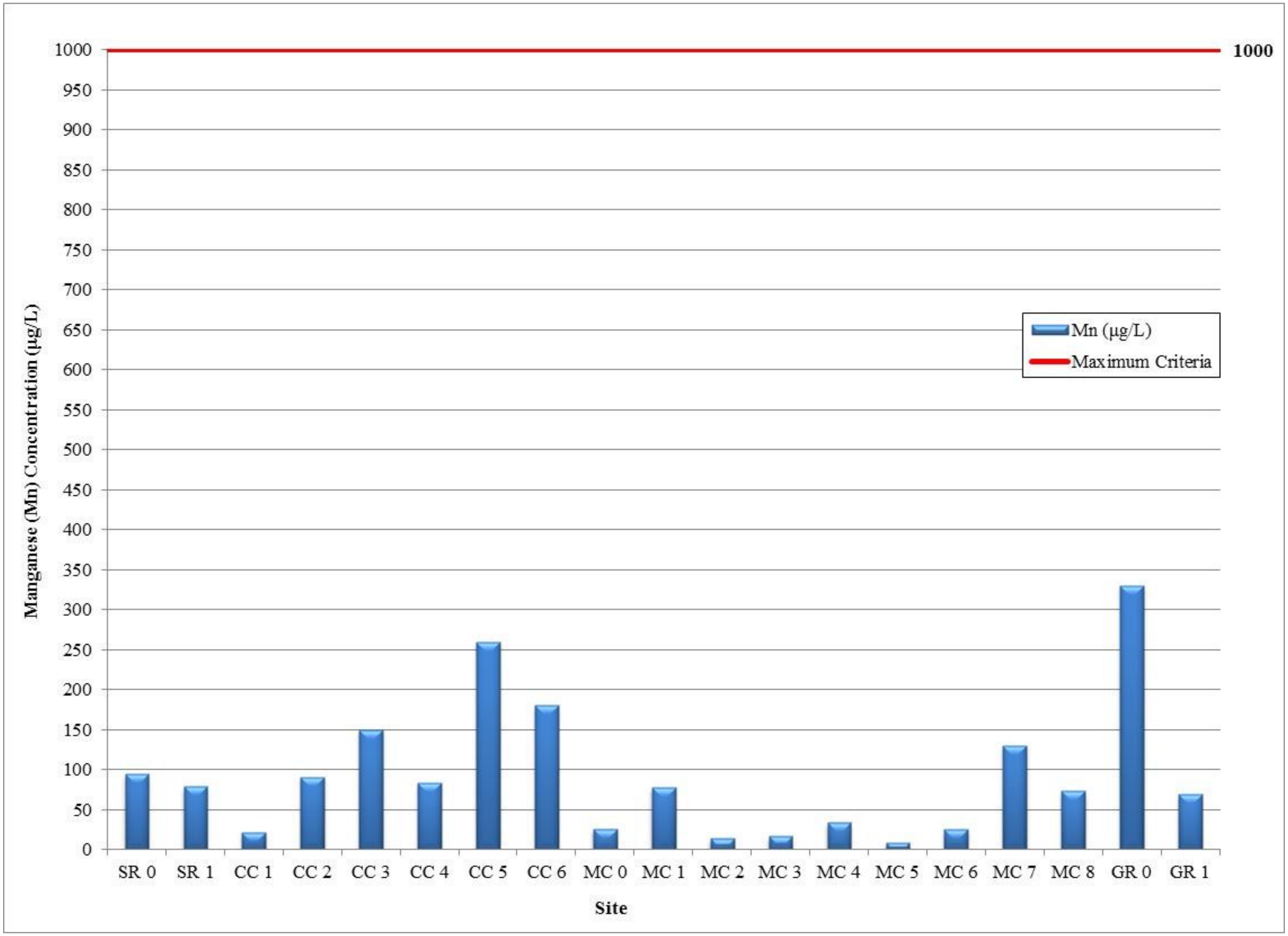

Figure 11. Manganese concentrations in the Presque Isle Bay watershed (2012)

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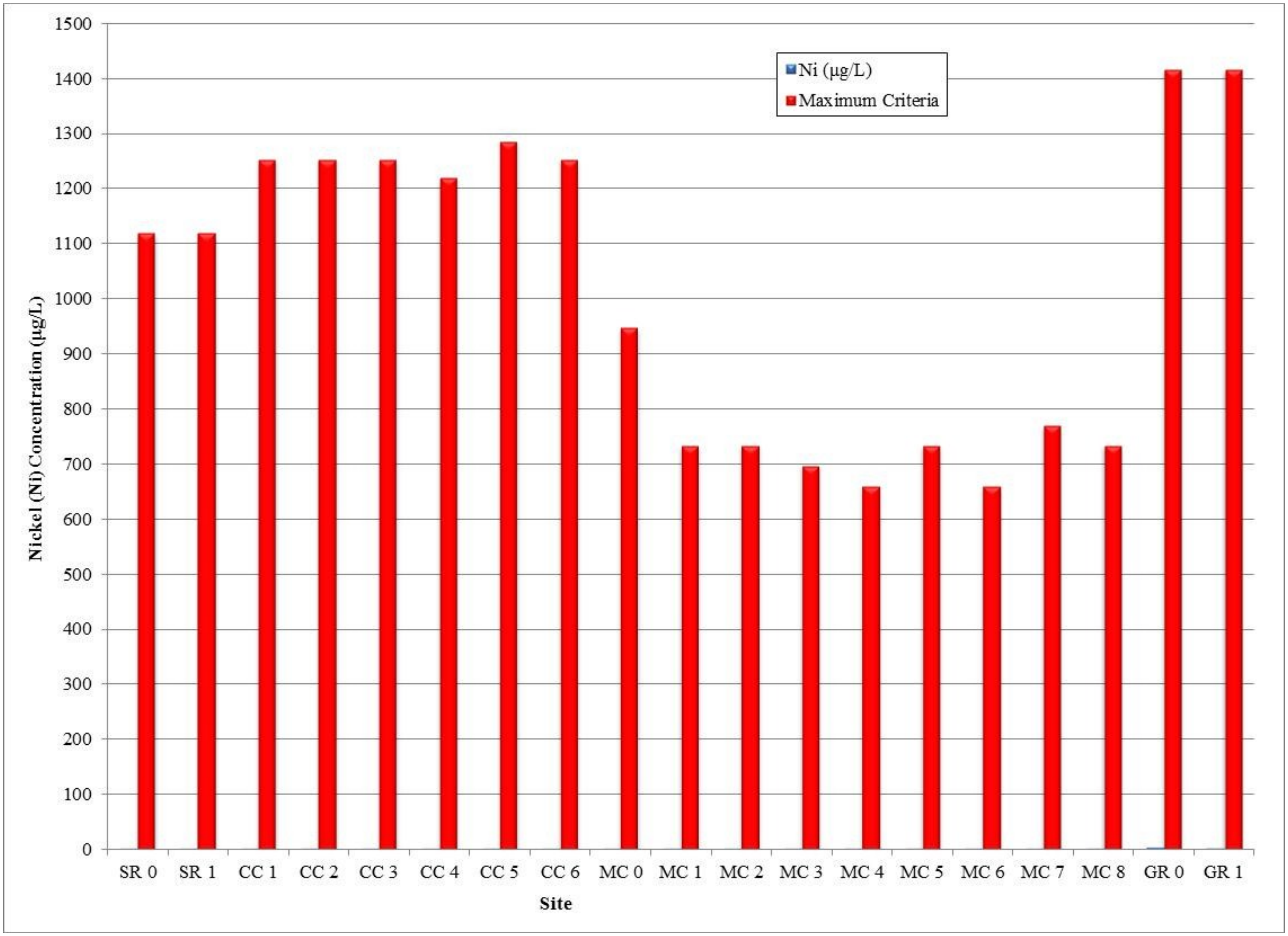

Figure 12. Nickel concentrations in the Presque Isle Bay watershed (2012)

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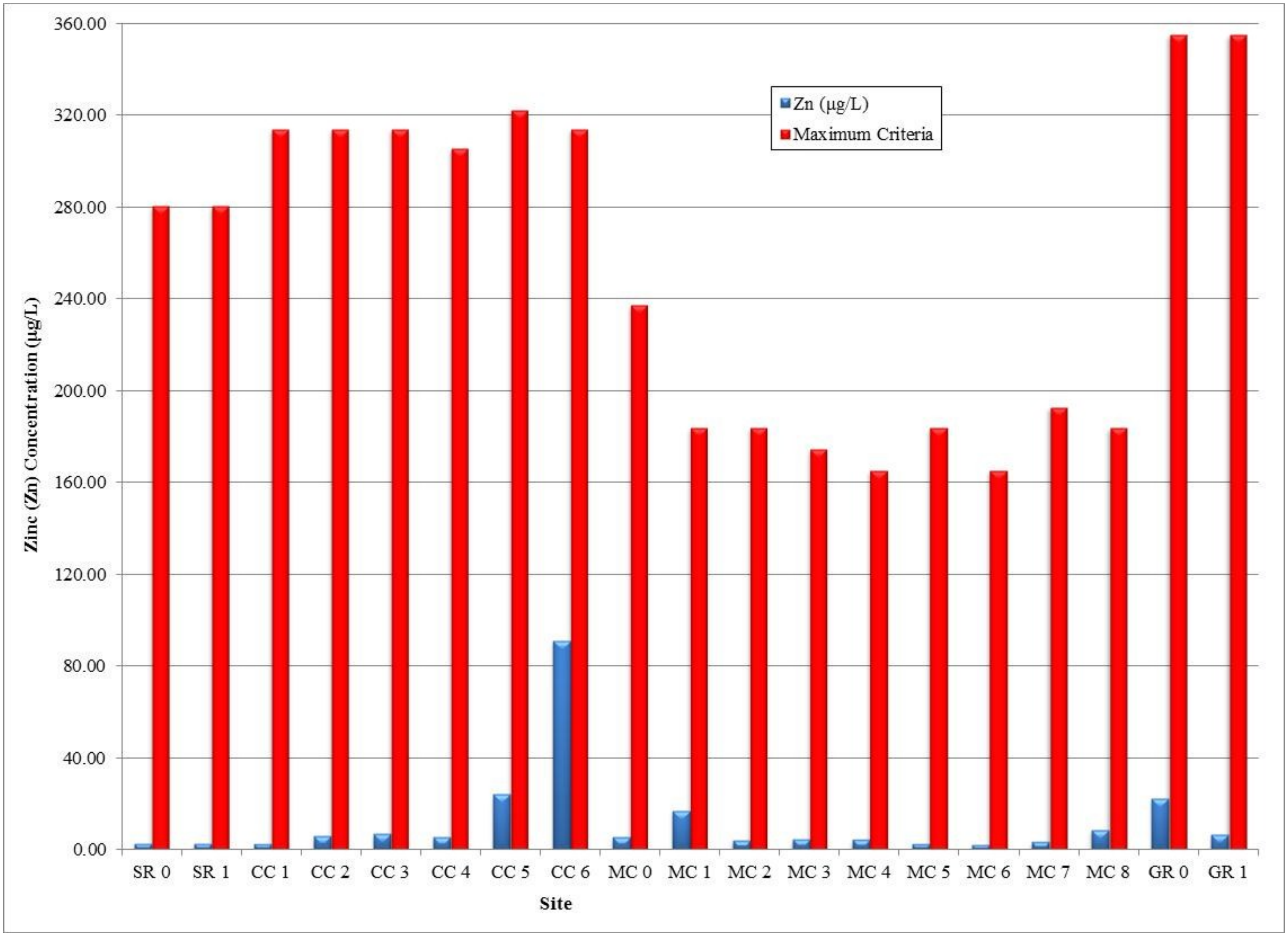

Figure 13. Zinc concentrations in the Presque Isle Bay watershed (2012)

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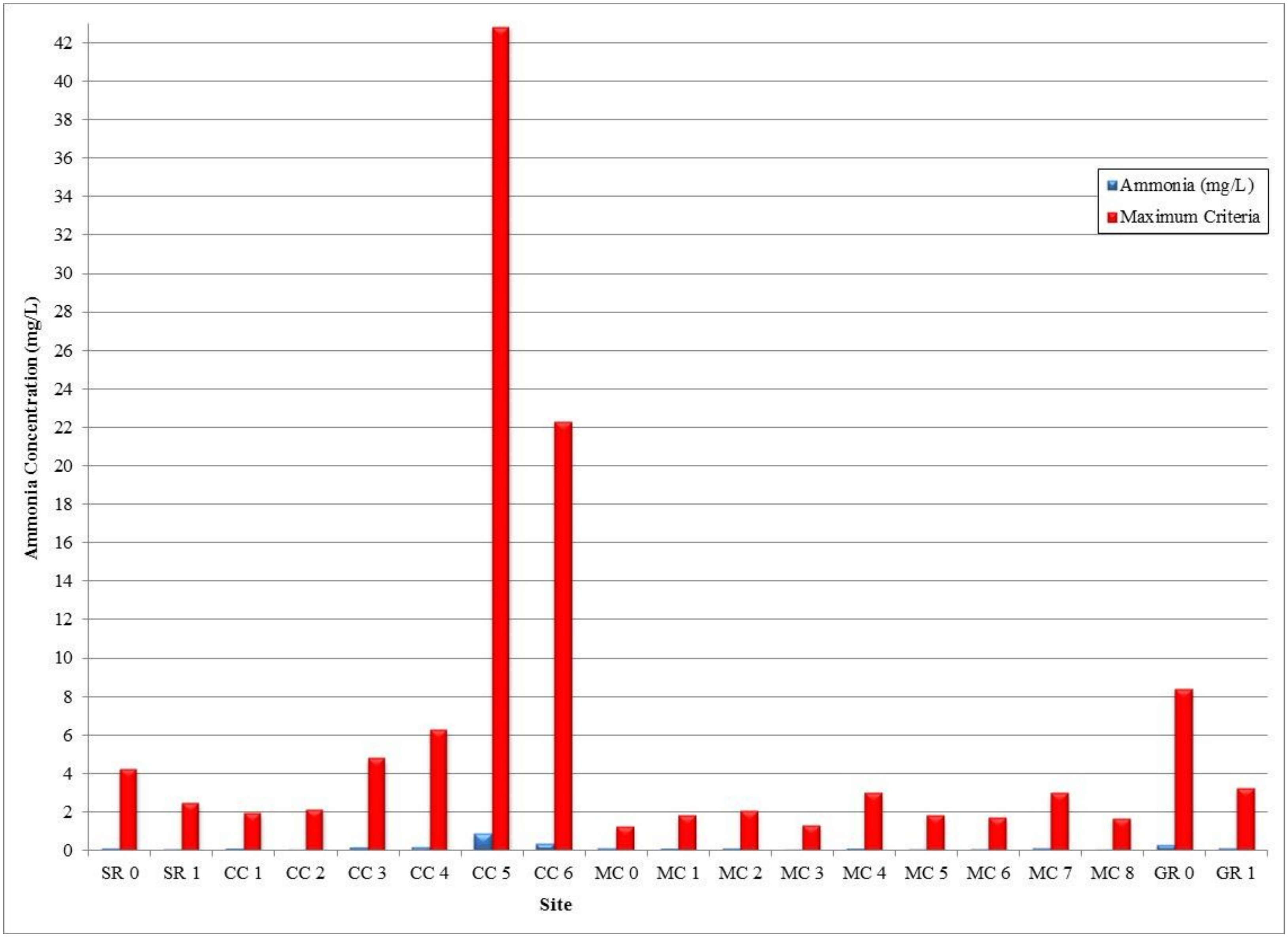

Figure 14. Ammonia concentrations in the Presque Isle Bay watershed (2012)

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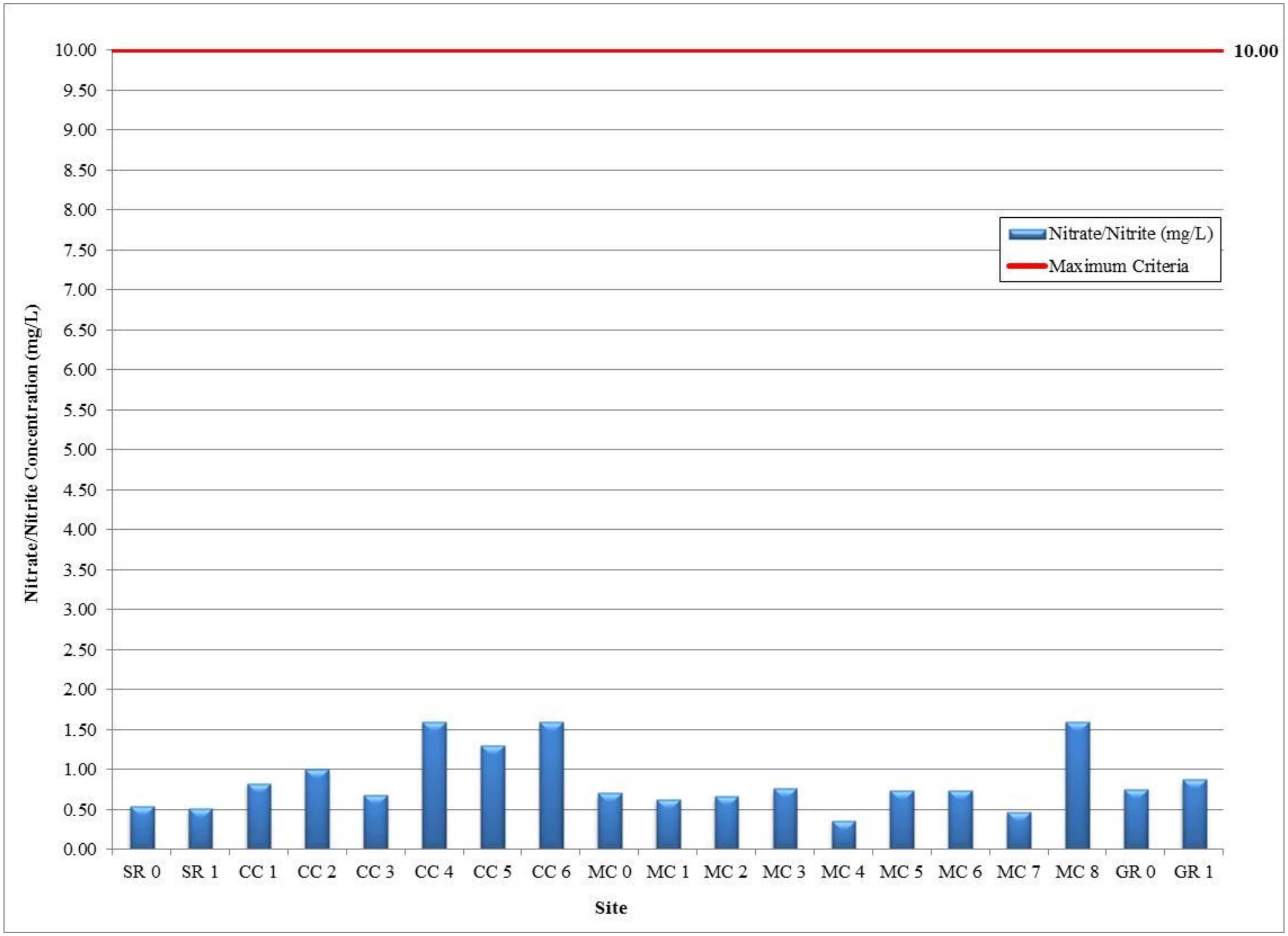

Figure 15. Nitrate/Nitrite concentrations in the Presque Isle Bay watershed (2012)

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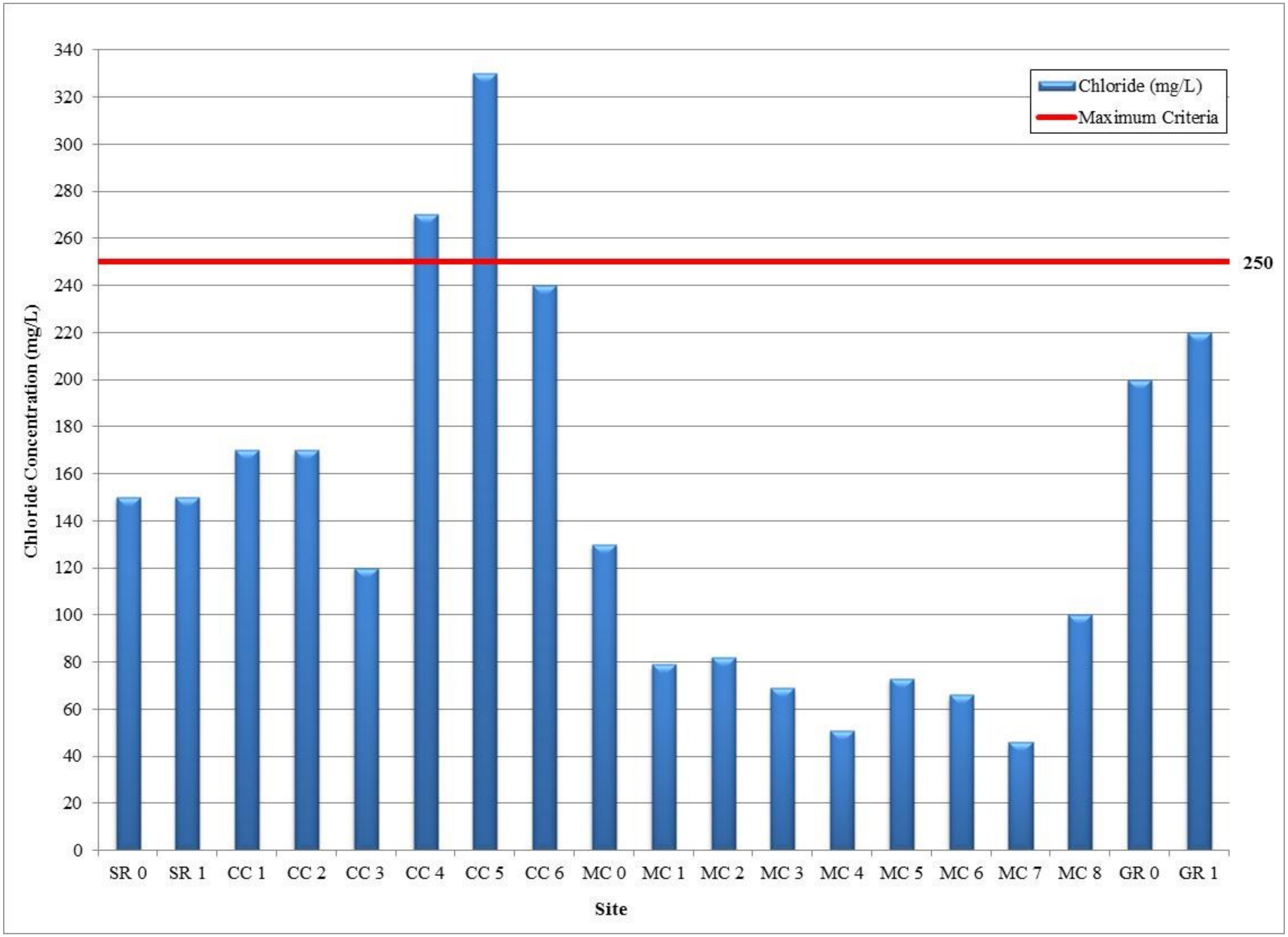

Figure 16. Chloride concentrations in the Presque Isle Bay watershed (2012)

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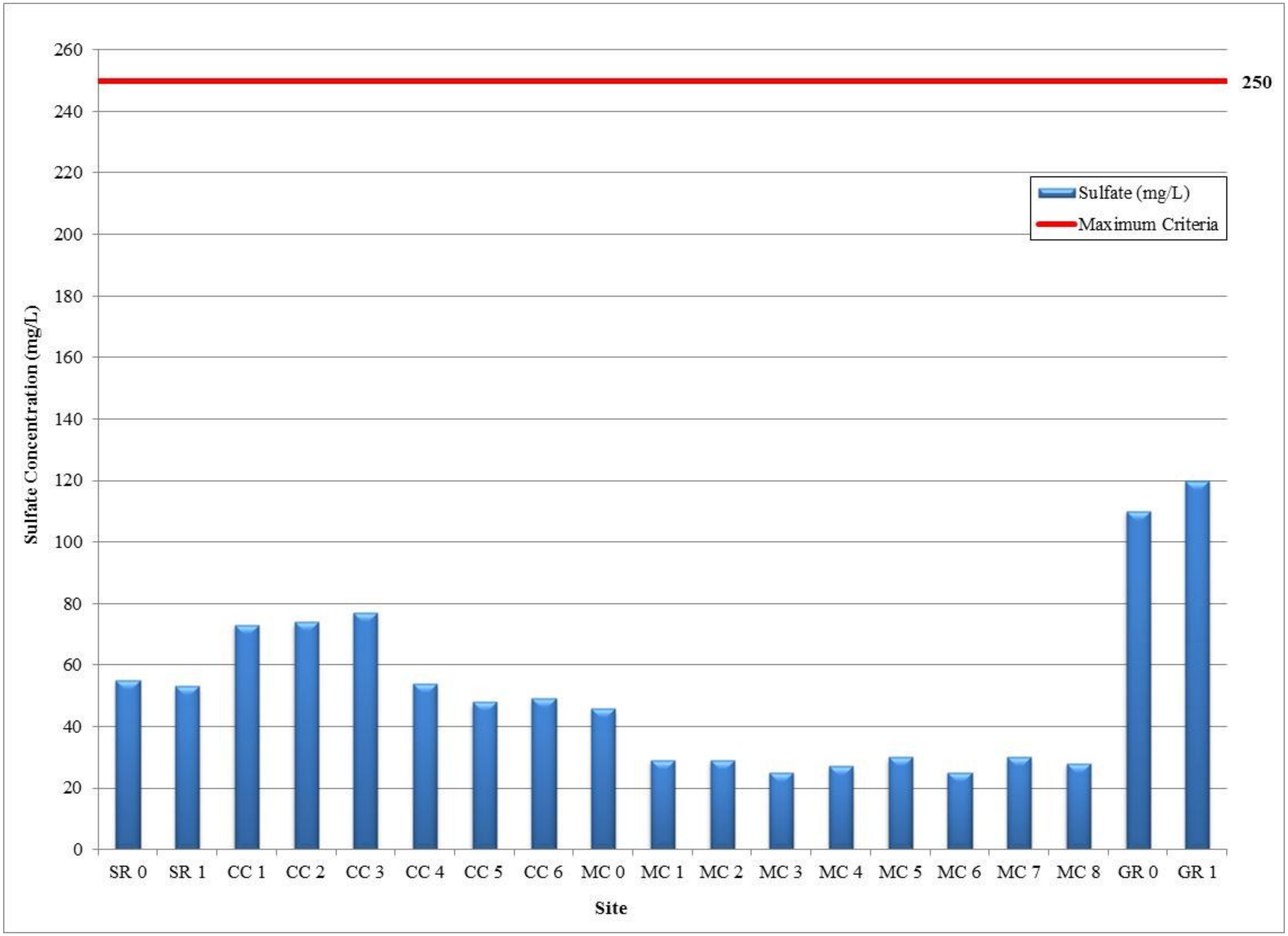

Figure 17. Sulfate concentrations in the Presque Isle Bay watershed (2012)

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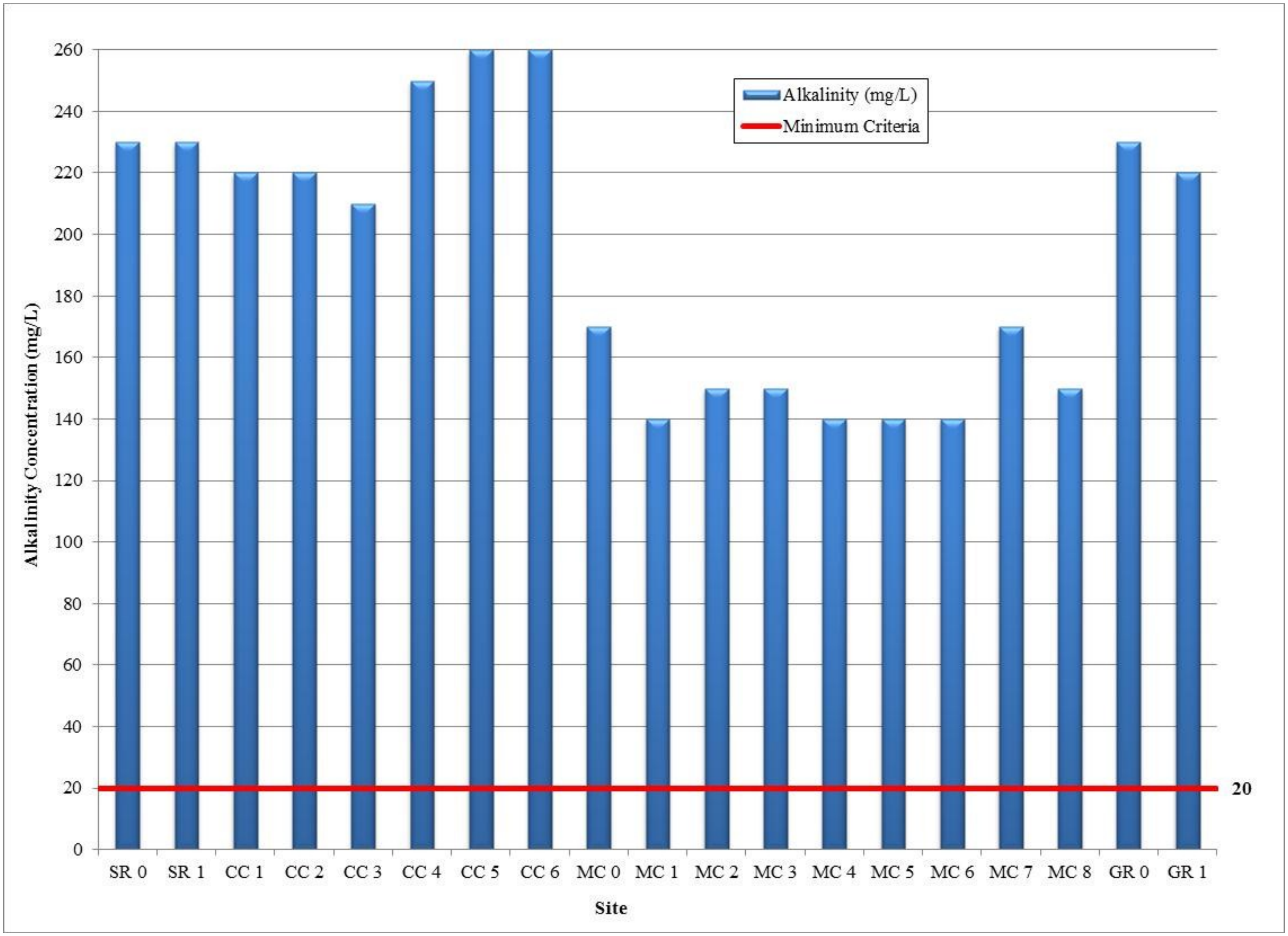

Figure 18. Alkalinity concentrations in the Presque Isle Bay watershed (2012)

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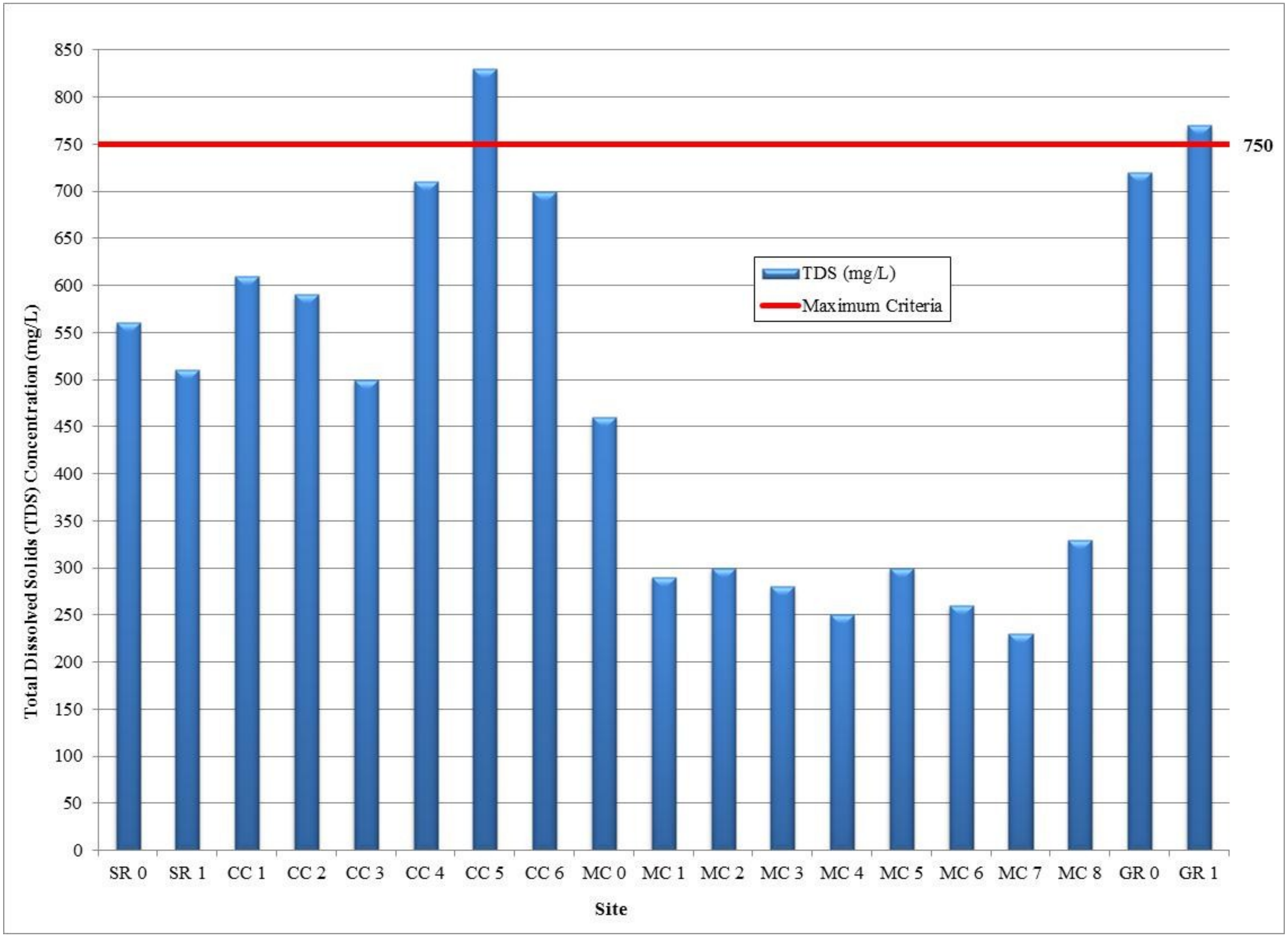

Figure 19. Total dissolved solids concentrations in the Presque Isle Bay watershed (2012)

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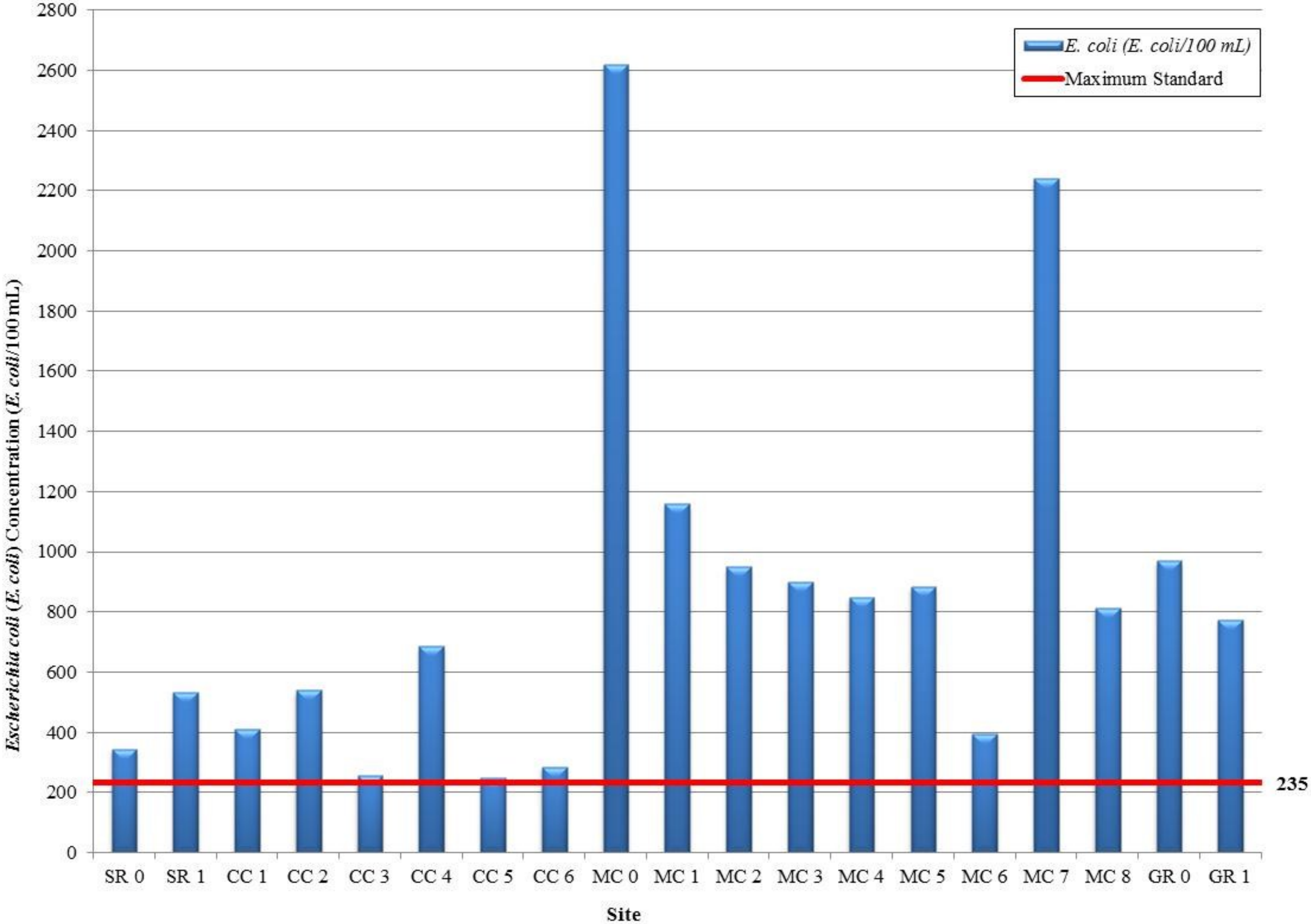

Figure 20. *E. coli* concentrations in the Presque Isle Bay watershed (2012)

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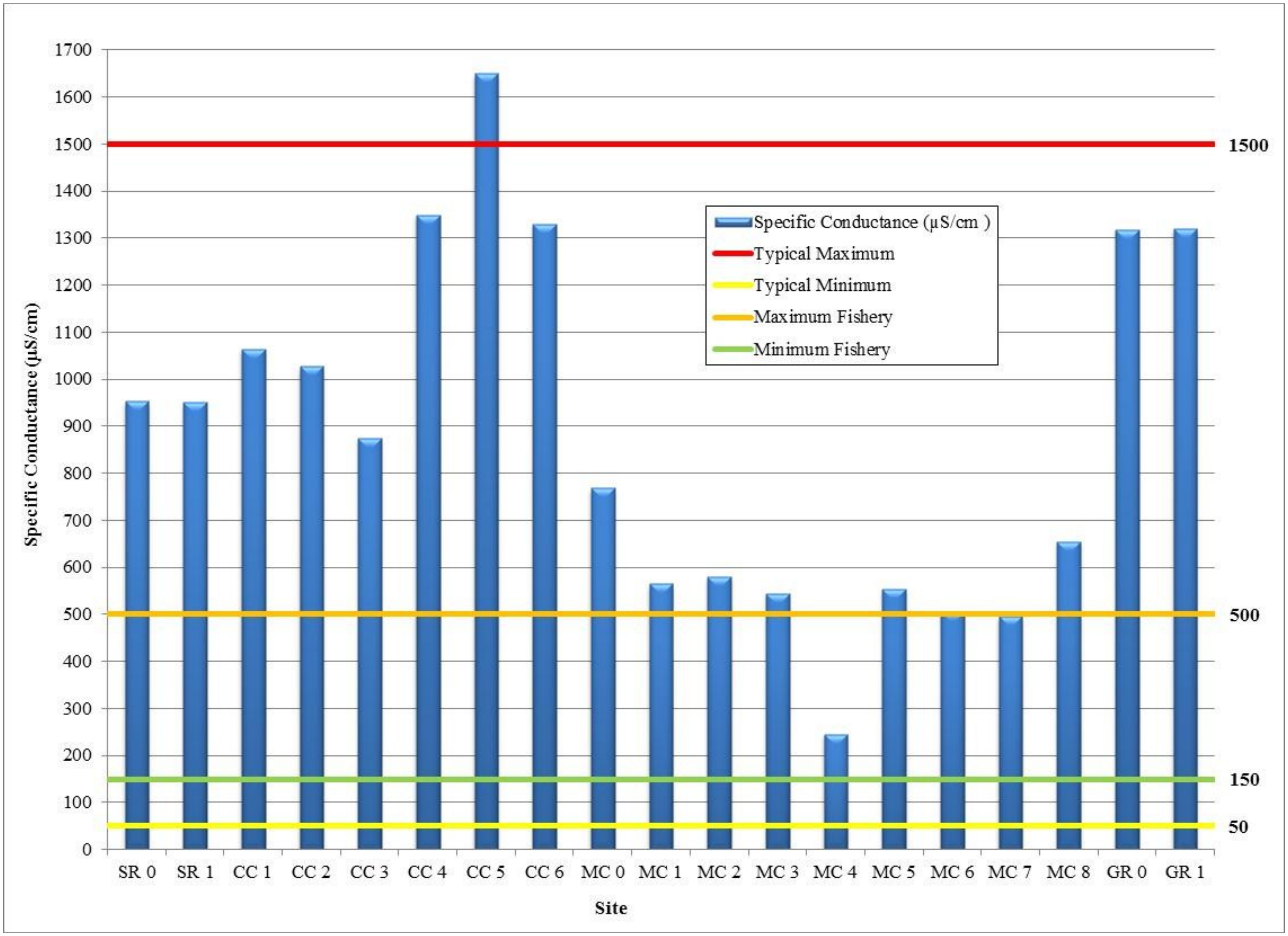

Figure 21. Specific conductance in the Presque Isle Bay watershed (2012)

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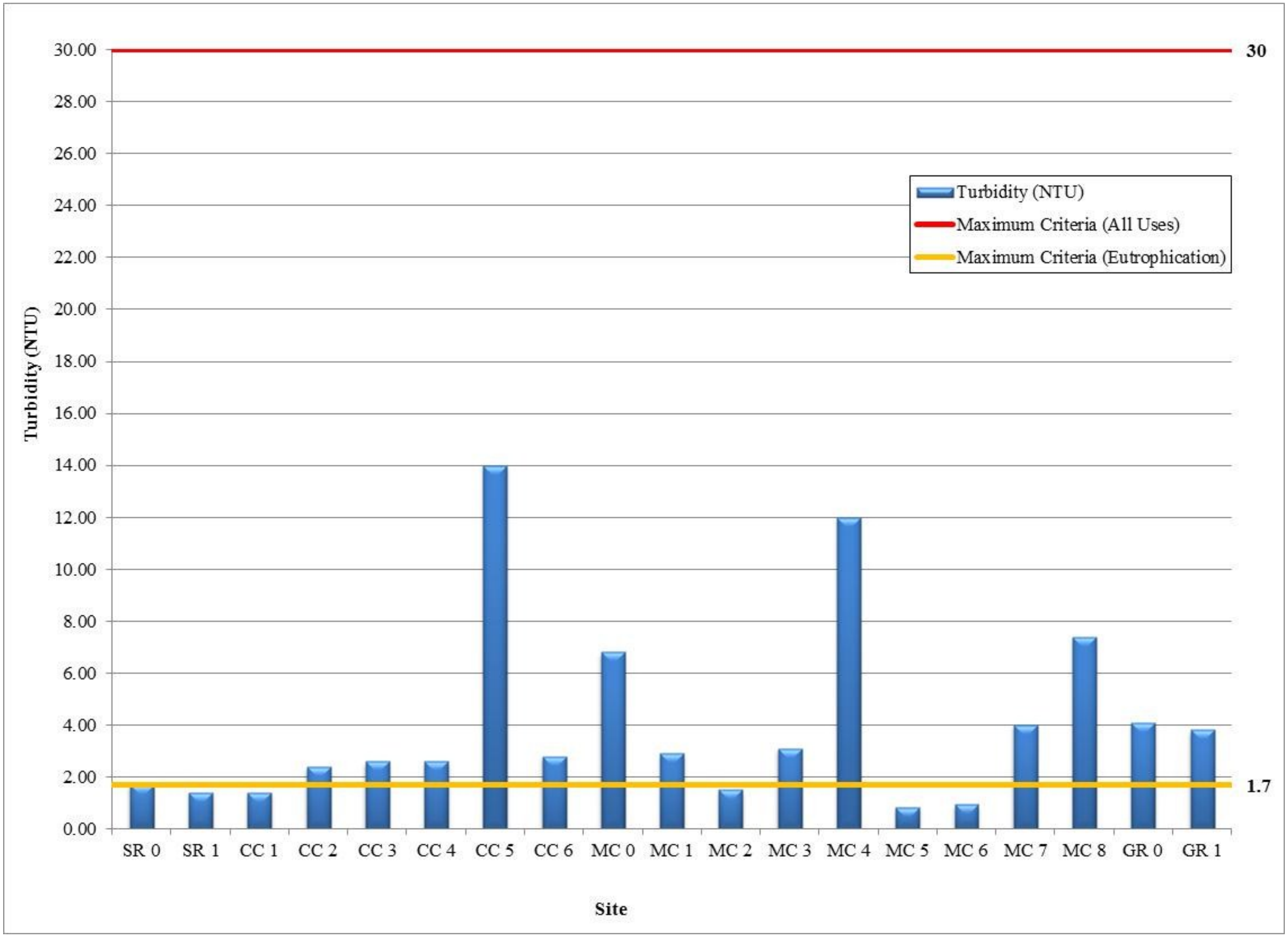

Figure 22. Turbidity in the Presque Isle Bay watershed (2012)

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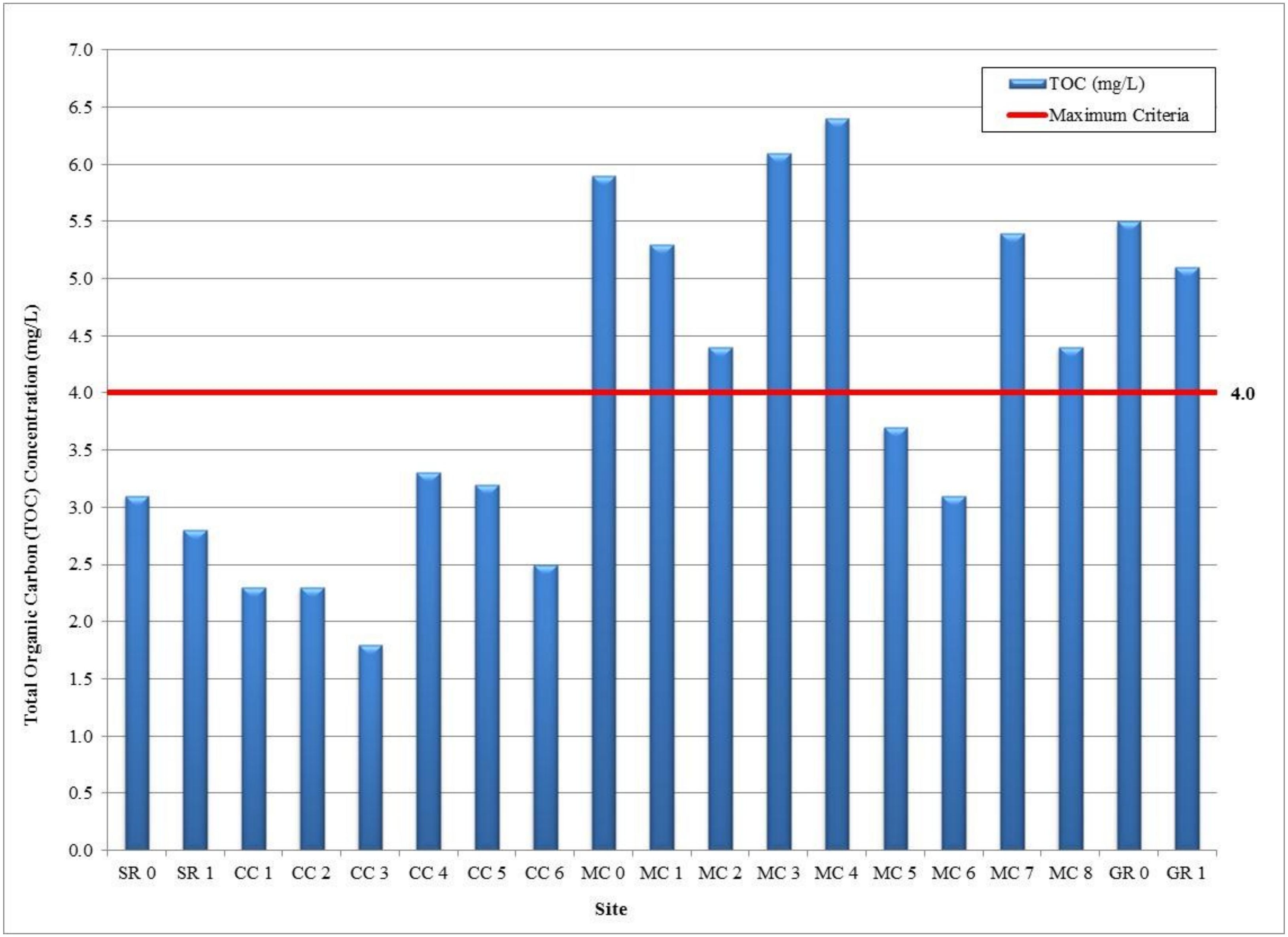

Figure 23. Total organic carbon concentrations in the Presque Isle Bay watershed (2012)

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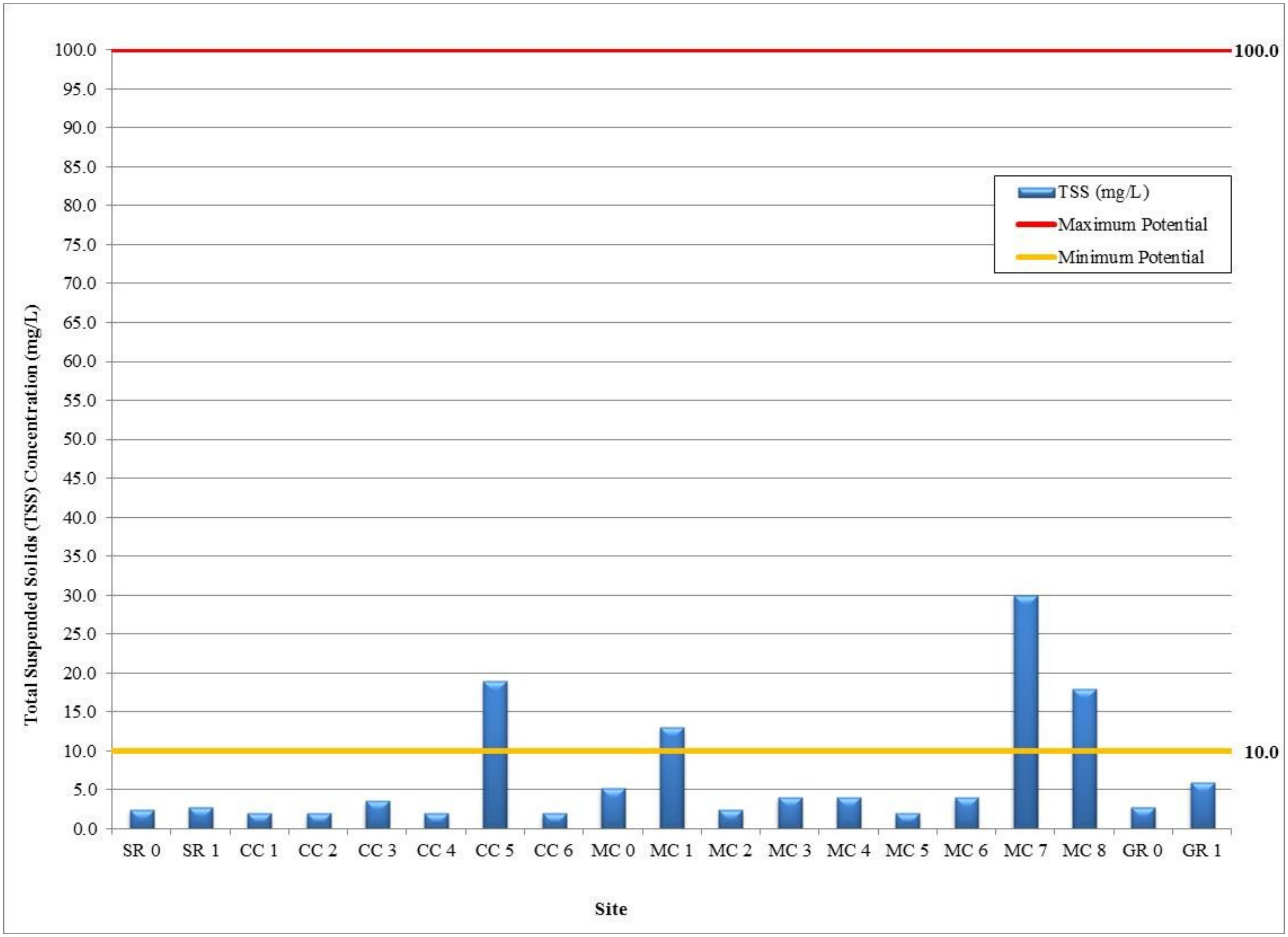

Figure 24. Total suspended solids concentrations in the Presque Isle Bay watershed (2012)

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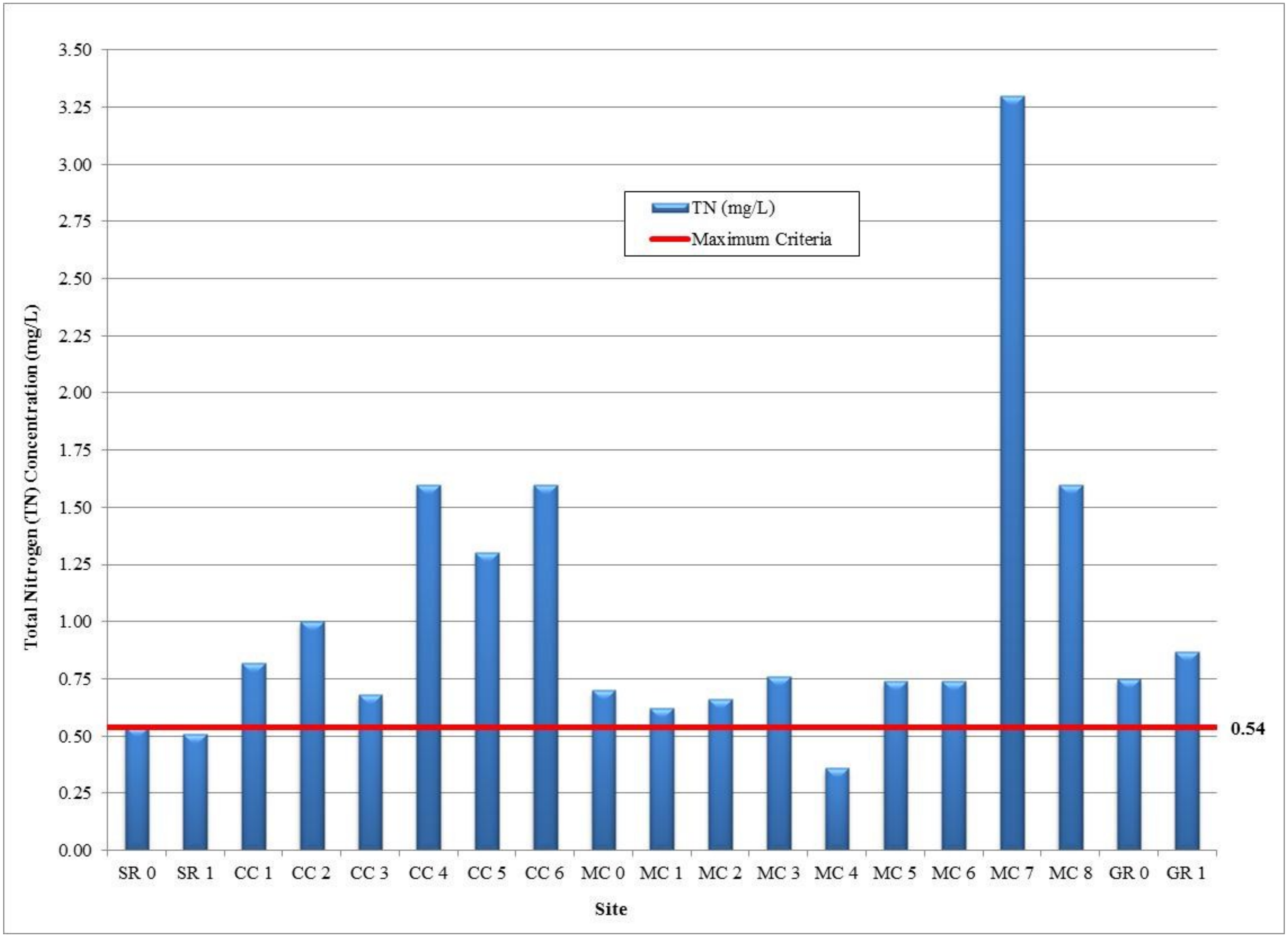

Figure 25. Total nitrogen concentrations in the Presque Isle Bay watershed (2012)

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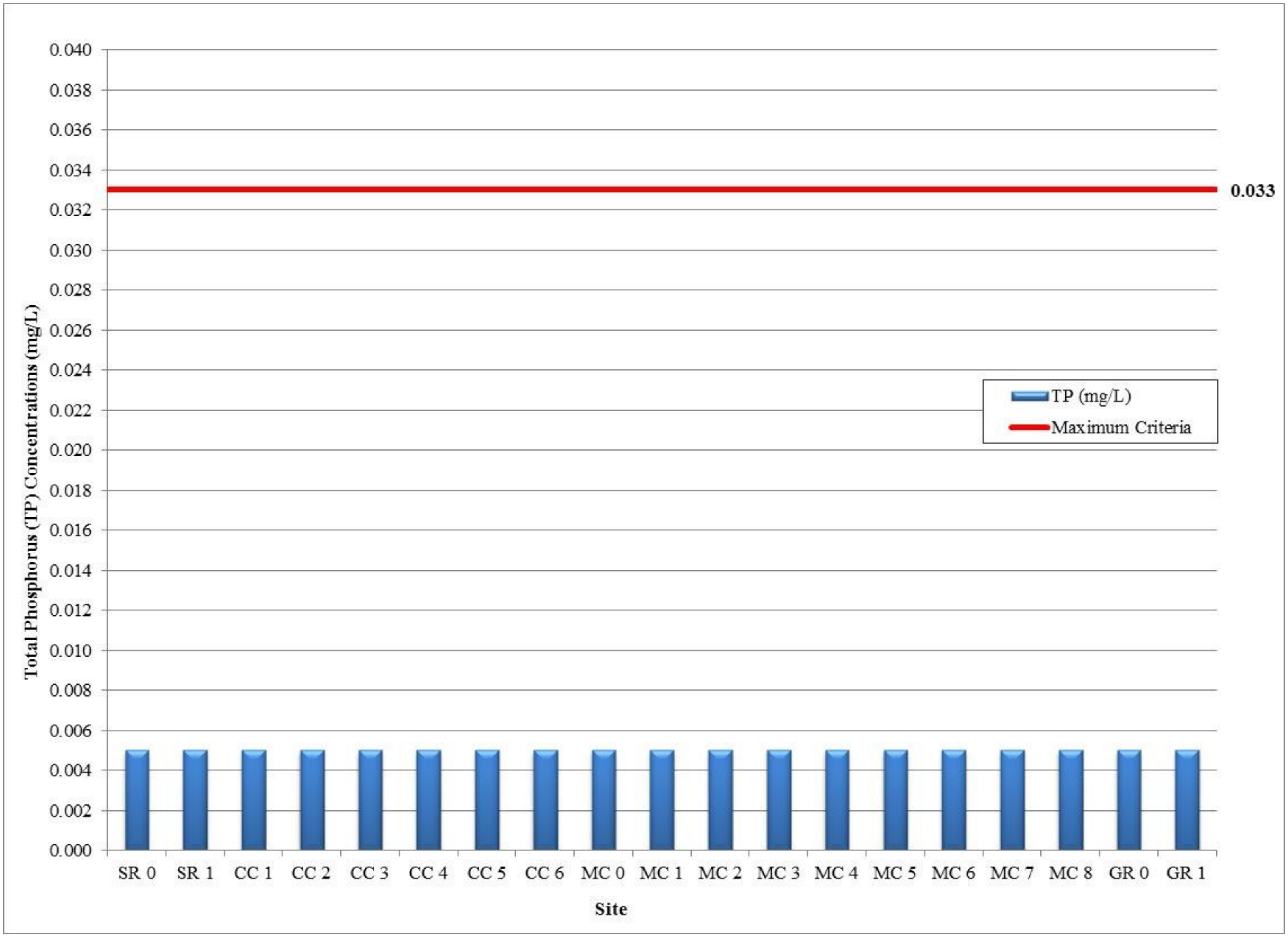

Figure 26. Total phosphorus concentrations in the Presque Isle Bay watershed (2012)

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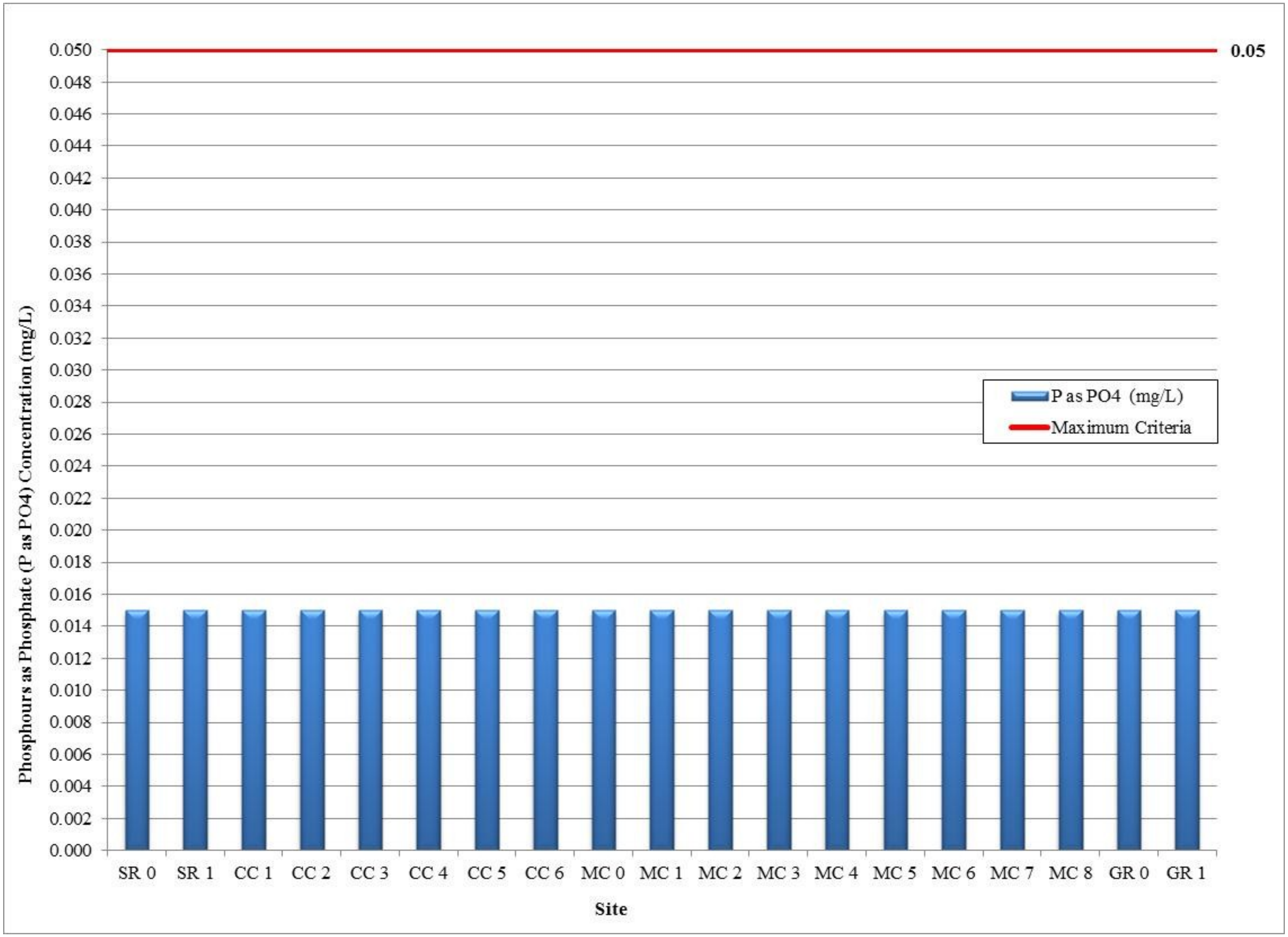

Figure 27. Phosphorus as phosphate concentrations in the Presque Isle Bay watershed (2012)

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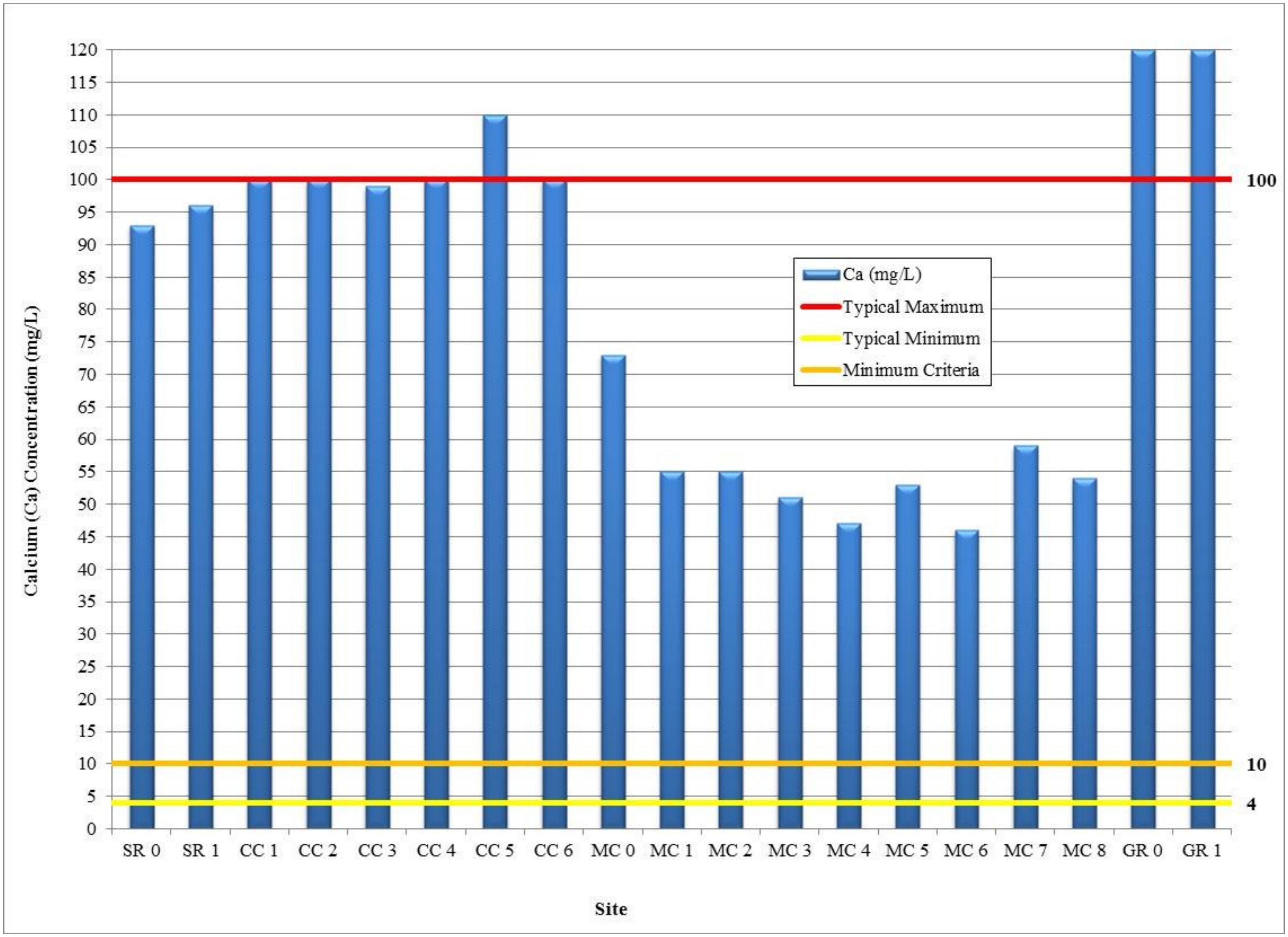

Figure 28. Calcium concentrations in the Presque Isle Bay watershed (2012)

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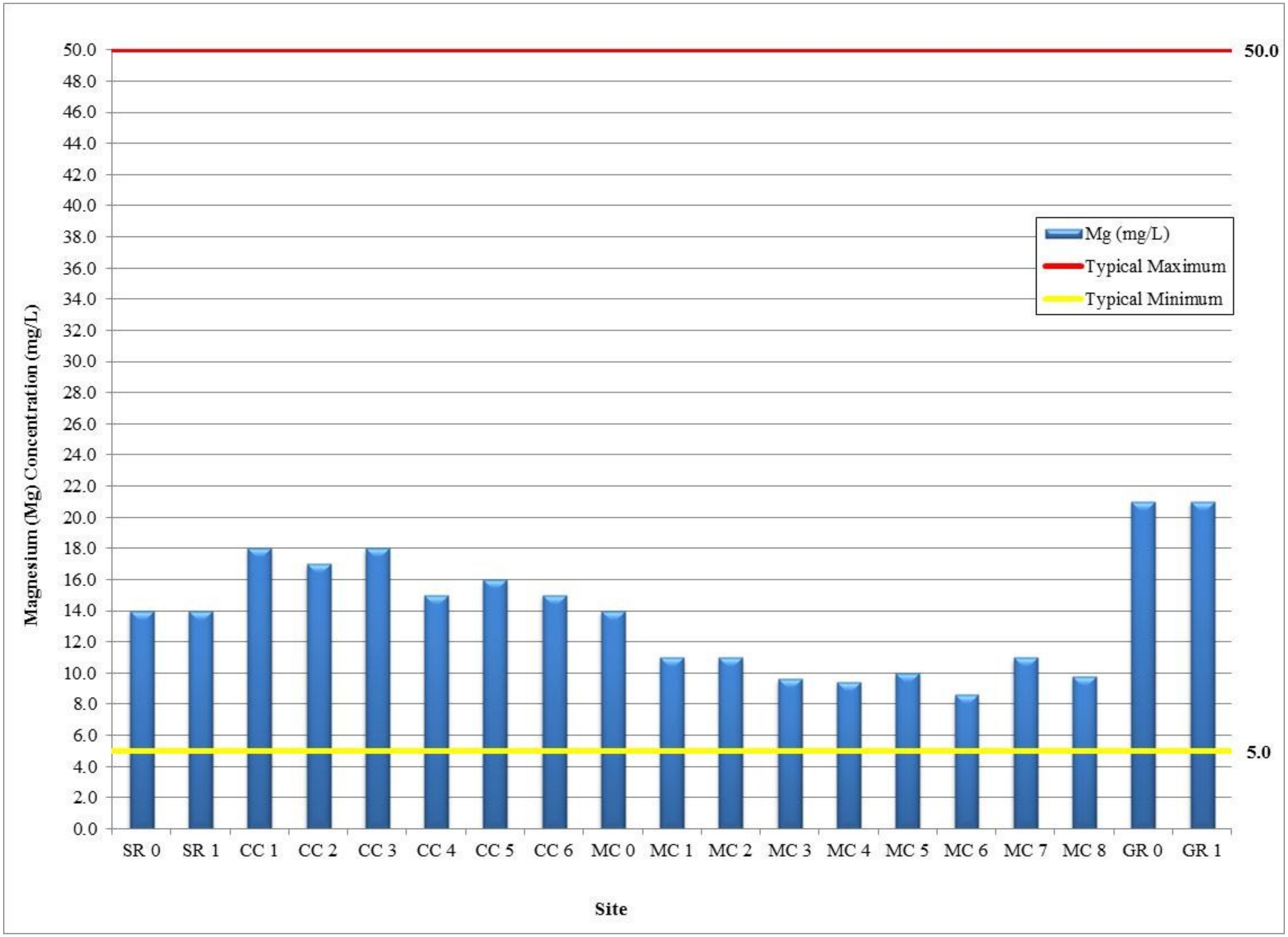

Figure 29. Magnesium concentrations in the Presque Isle Bay watershed (2012)

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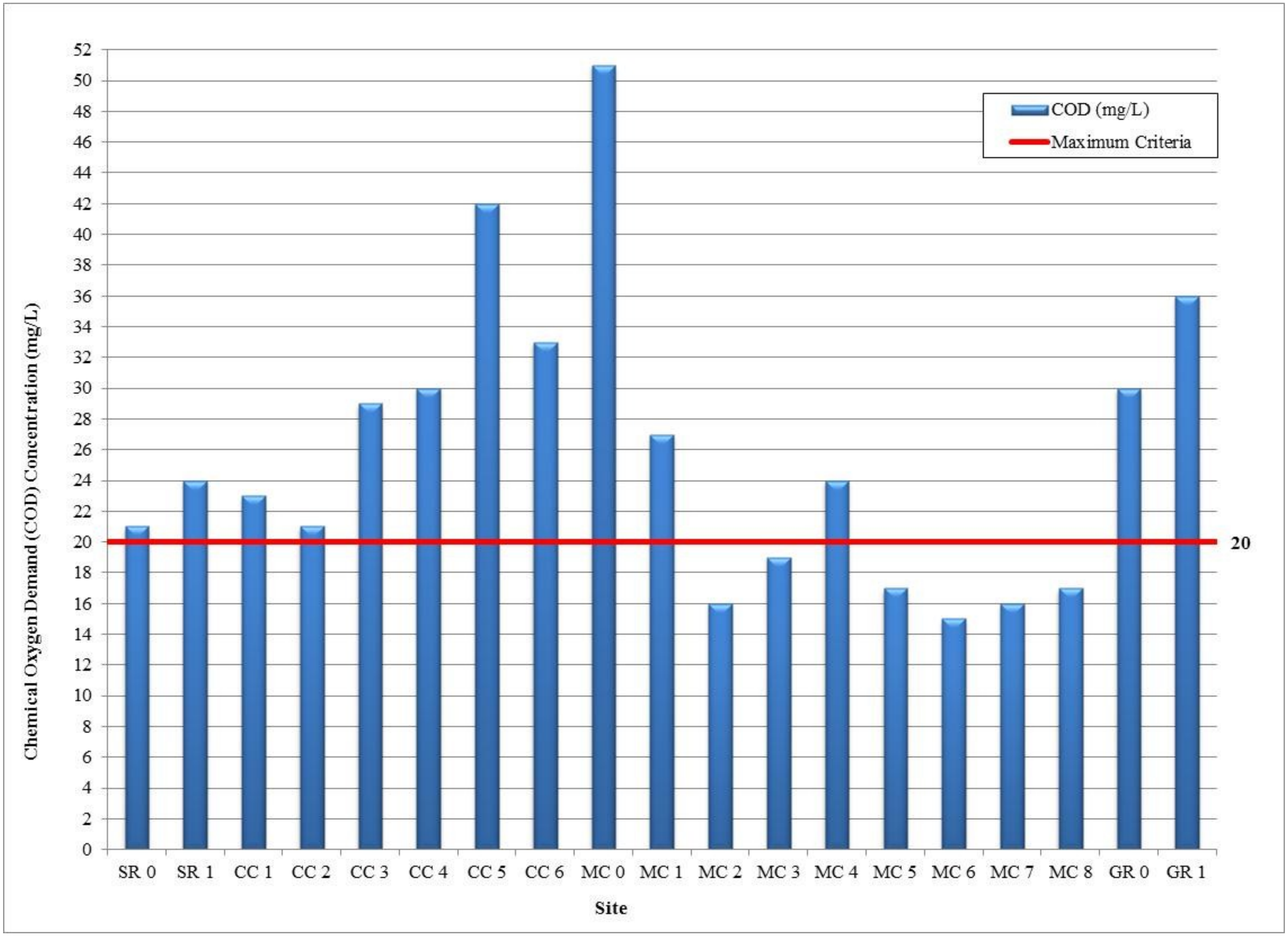

Figure 30. Chemical oxygen demand concentrations in the Presque Isle Bay watershed (2012)

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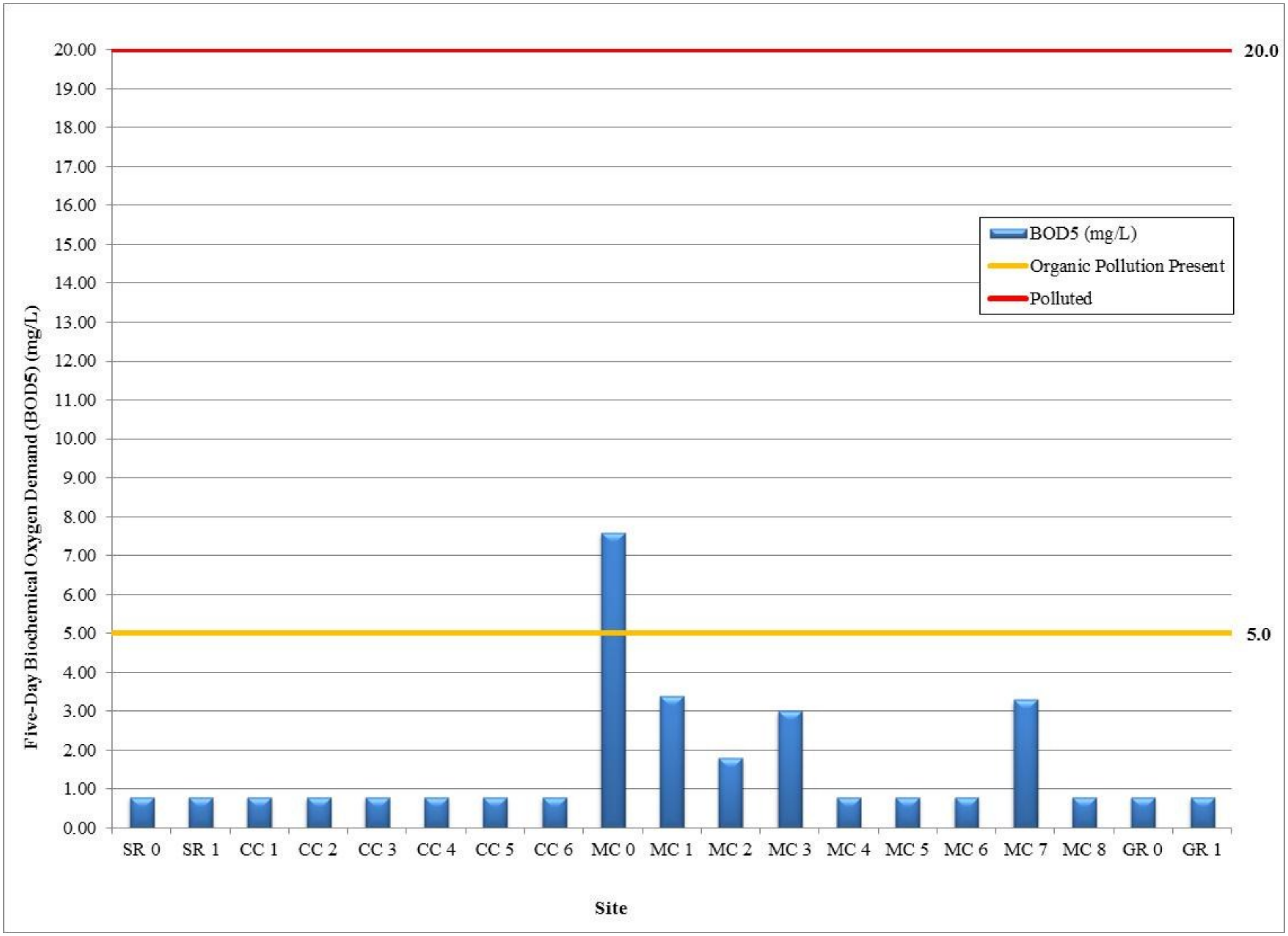

Figure 31. Five-day biochemical oxygen demand concentrations in the Presque Isle Bay watershed (2012)

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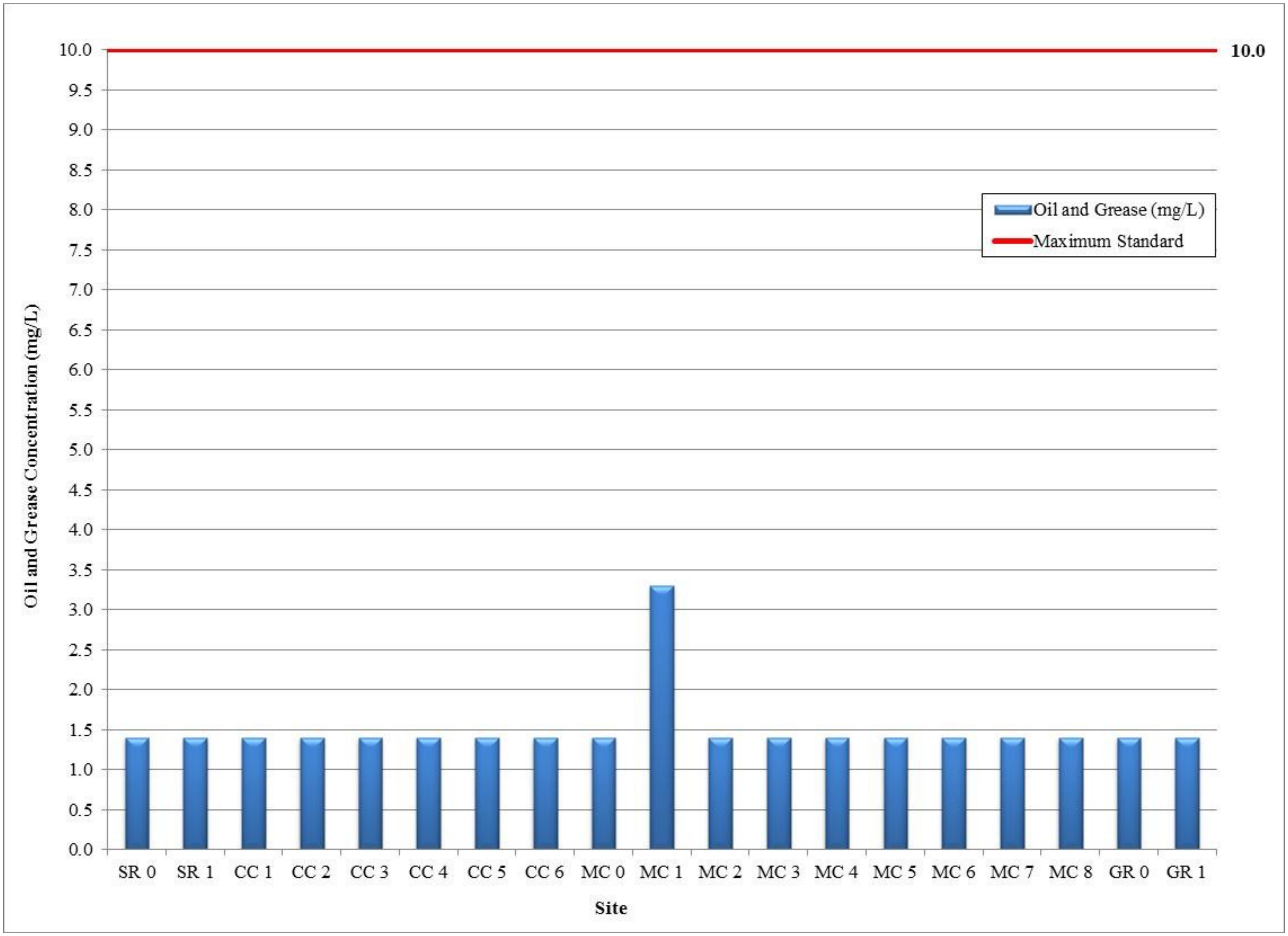

Figure 32. Oil and grease concentrations in the Presque Isle Bay watershed (2012)

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APPENDIX B: TABLES

Table 1. Presque Isle Bay Watershed Water Quality Sampling Locations (2012)

Stream Location	Site Name	Historic Site Name	Latitude	Longitude
Mill Creek 0	MC 0	TRIB-MC-01-2009	42.14109	-80.07857
Mill Creek 1	MC 1	MC 1	42.10591	-80.07296
Mill Creek 2	MC 2	MC 2	42.09386	-80.07077
Mill Creek 3	MC 3	MC 3	42.08559	-80.07129
Mill Creek 4	MC 4	MC 4	42.07889	-80.0522
Mill Creek 5	MC 5	MC 5	42.0919	-80.05621
Mill Creek 6	MC 6	MC 6	42.10282	-80.02713
Mill Creek 7	MC 7	MC 7	42.10297	-80.02772
Mill Creek 8	MC 8	MC 8	42.0909	-80.01591
Cascade Creek 1	CC 1	CC 1	42.12634	-80.11095
Cascade Creek 2	CC 2	CC 2	42.11712	-80.11689
Cascade Creek 3	CC 3	CC 3	42.11359	-80.11610
Cascade Creek 4	CC 4	CC 4	42.11131	-80.1205
Cascade Creek 5	CC 5	CC 5	42.10602	-80.13167
Cascade Creek 6	CC 6	CC 6	42.10173	-80.13094
Scott Run 0	SR 0	TRIB-SR-01-2009	42.11172	-80.15498
Scott Run 1	SR 1	SR	42.11241	-80.15384
Garrison Run 0	GR 0	TRIB-GR-01-2009	42.14365	-80.07577
Garrison Run 1	GR 1	GR	42.14176	-80.07323

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Table 2. Water Quality Sampling Protocols

ID	Sets	Bottles per Set	Total Bottles	Bottle Type - Description	Preservative	Filter	Method
1	20	1	20	Plastic 500ml w/ Sulfuric Acid	Sulfuric Acid	No	350.1 - Ammonia, distilled 410.4 - Chemical Oxygen Demand Nitrogen, Total - total nitrogen
2	20	1	20	Plastic 500ml unpreserved	None	No	2320B - Alkalinity 180.1 - Turbitiy SM2540B - Residue, Total 300.0_28D_Anions 300 - (MOD) 48HR Anions
3	20	1	20	Plastic 250ml unpreserved	None	No	300 - Orthophosphate
4	20	1	20	Plastic 500ml w/ Nitric Acid	Nitric Acid	No	2340C - Hardness as Calcium CaCO3 200.7 - (MOD) Special list 200.7 245.1 - Mercury
5	20	2	40	Plastic 1 liter unpreserved	None	No	5210B - BOD SM2530F - Settable Solids
6	20	1	20	Plastic 500ml unpreserved	None	No	2540D - Total Suspended Solids
7	20	1	20	Plastic 500ml unpreserved	None	No	2540C - Total Dissolved Solids
8	20	2	40	Voa Vial 40ml Amber w/ Sulfuric Acid	Sulfuric Acid	No	5310C - TOC Result 1
9	20	2	40	Amber Glass 1 liter w/ Sulfuric Acid	Sulfuric Acid	No	1664A - HEM (Oil and Grease)
10	20	1	20	Plastic 250ml w/ Sulfuric Acid (dis)	Sulfuric Acid	Yes	4500P_E - Dissolved Phosphorus
11	20	1	20	Plastic 250ml w/ Sulfuric Acid	Sulfuric Acid	No	4500P_E - Total Phosphorus
12	20	2	40	Bacti 125ml	None	No	RSC - Fecal Coliform

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Table 3. Water Quality Standards and Criteria

Parameter	Criteria	Source	Critical Use[a]
Temperature (°F)	Maximum 60; 80; 70	PA Ch. 93 WQ Standards	CWF; WWF; TSF
Specific Conductance	150 < 500 µS/cm; 50 < 1500 µS/cm	EPA (1997)	Streams supporting healthy fisheries; US rivers range
DO	Minimum 5.0 mg/L	PA Ch. 93 WQ Standards	CWF; HQ-WWF; HQ-TSF; WWF; TSF
pH	6.0 > 9.0	PA Ch. 93 WQ Standards	CWF; WWF; TSF; MF
E.coli	Maximum 235 *E.coli/100 mL*	EPA (2011)	Recreational use
Mercury	Maximum 1.44 µg/L; 0.0031 µg/L	PA Ch. 93 WQ Standards	Aquatic life/fish; Human health
Aluminum	Maximum 750 µg/L	PA Ch. 93 WQ Standards	Aquatic life/fish
Cadmium	Maximum{1.136672-(ln[H]×0.041838)} × Exp(1.128×ln[H]-3.6867) µg/L	PA Ch. 93 WQ Standards	Aquatic life/fish
Calcium	4 < 100 mg/L; Minimum 10 mg/L	Lehigh University	Typical freshwaters; support plants and animals
Chromium	Maximum 15.73 µg/L	PA Ch. 93 WQ Standards	Aquatic life
Copper	Maximum (0.960×Exp(0.9422×ln[H]-1.700) µg/L	PA Ch. 93 WQ Standards	Aquatic life/fish
Iron	Maximum 0.3 mg/L	PA Ch. 93 WQ Standards	PWS
Lead	Maximum {1.46203-(ln[H]×0.145712)}× Exp(1.273×ln[H]-1.460) µg/L	PA Ch. 93 WQ Standards	Aquatic life
Magnesium	5 < 50 mg/L	Lehigh University	Typical freshwaters
Manganese	Maximum 1.0 mg/L	PA Ch. 93 WQ Standards	PWS
Nickel	Maximum 0.998 × Exp(0.846 × ln[H] +2.255) µg/L	PA Ch. 93 WQ Standards	Aquatic life/fish
Zinc	Maximum 0.978 × Exp(0.8473×ln[H] +0.884) µg/L	PA Ch. 93 WQ Standards	Aquatic life/fish
Ammonia	≤ [NH3-N] × ($\log^{-1}$[pK_T-pH] + 1) mg/L	PA Ch. 93 WQ Standards	CWF, WWF, TSF, MF
COD	Maximum 20 mg/L	NOAA NERRS	Indication of pollution
Hardness	N/A	N/A	N/A
Oil and Grease	< 10 mg/L	WY Ch. 1 WQ Standards	N/A
Turbitiy	Maximum 30 NTU; maximum 1.70 NTU	EPA (1988); EPA (2000)	All uses; Protect against eutrophication
Nitrate + Nitrite	Maximum 10 mg/L	PA Ch. 93 WQ Standards	PWS
Chloride	Maximum 250 mg/L	PA Ch. 93 WQ Standards	PWS
Sulfate	Maximum 250 mg/L	PA Ch. 93 WQ Standards	PWS
Orthophosphate	Maximum 0.05 mg/L	Dunne and Leopold (1978)	Prevent long-term eutrophication
Alkalinity	Minimum 20 mg/L	PA Ch. 93 WQ Standards	CWF, WWF, TSF, MF
Total Solids	N/A	N/A	N/A
Total Dissolved Solids	Maximum 750 mg/L	PA Ch. 93 WQ Standards	PWS
Total Suspended Sol-	< 10 mg/L; 10 < 100 mg/L; > 100 mg/L	Mills et al. (1985)	Improbable; potential; probable impairment of
Settable Solids	N/A	N/A	N/A
5-day BOD	5 < 20 mg/L; > 20 mg/L	Diz and Johnson (2002)	Organic pollution present; Polluted with organic matter
Total Organic Carbon	Maximum 4.0 mg/L	EPA (2010)	Prevent trihalomethane formation in raw drinking water subject to chlorination
Total Nitrogen	Maximum 0.54 mg/L	EPA (2000)	Protect against eutrophication
TKN	Maximum 0.24 mg/L	EPA (2000)	Protect against eutrophication
Total Phosphorus	Maximum 33 µg/L	EPA (2000)	Protect against eutrophication
Phosphorus as PO_4	Maximum 0.05 mg/L	EPA (1976)	Prevent accelerated eutrophication

[a] CWF = cold water fishes; WWF = warmwater fishes; TSF = trout stocking; MF = migratory fishes; PWS = potable water supply; ln[H] = natural logarithm of hardness of stream (mg/L as $CaCO_3$)

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APPENDIX C: MAPS

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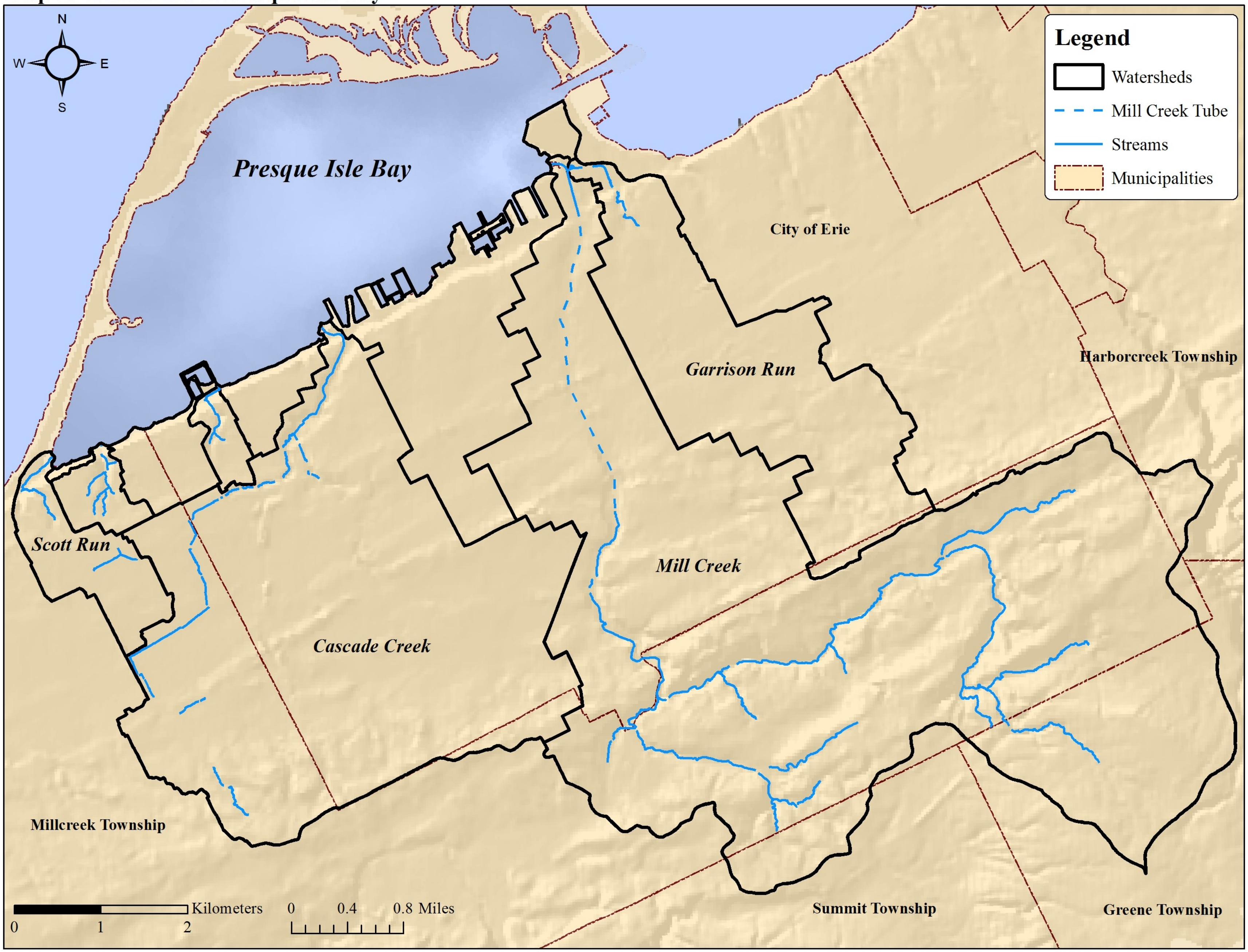
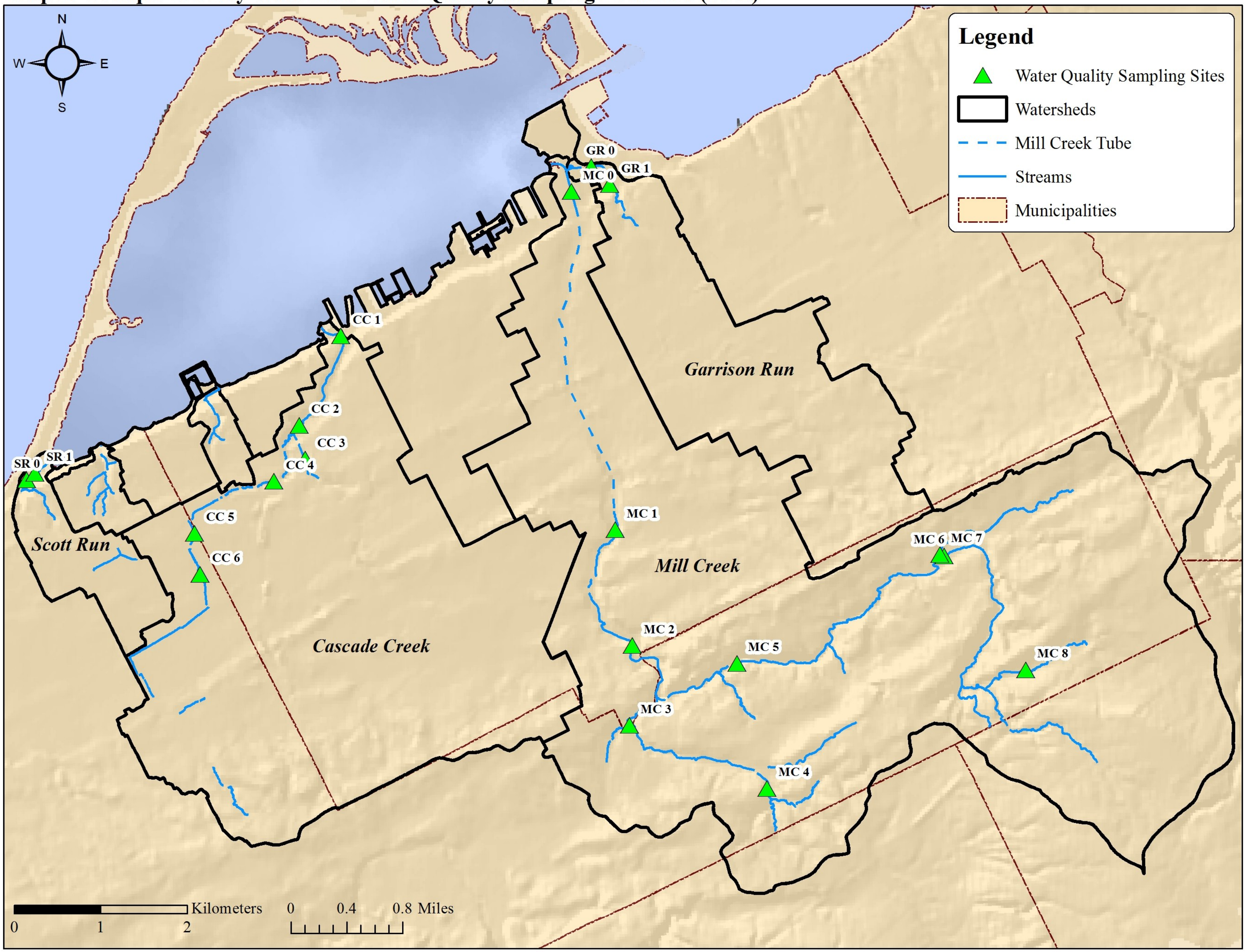
Map 1: Tributaries of Presque Isle Bay



Map 2: Presque Isle Bay Watershed Water Quality Sampling Locations (2012)



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APPENDIX D: 2012 WATER CHEMISTRY DATA

Appendix D. 2012 Preseque Isle Bay tributary water quality data

	Site																		
Parameter	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	GRO	GR1
Temp (°F)	60.89	61.25	63.52	61.07	59.00	63.64	68.14	62.20	66.47	66.02	65.59	64.44	63.90	65.80	66.76	65.70	62.69	69.96	65.26
Temp (°C)	16.05	16.25	17.51	16.15	15.00	17.58	20.08	16.78	19.15	18.90	18.66	18.02	17.72	18.78	19.31	18.72	17.05	21.09	18.48
Sp. Conductance (µS/cm)	953	951	1064	1027	874	1349	1650	1330	768	565	579	545	245	554	506	496	655	1318	1320
DO (mg/L)	7.71	8.14	8.32	7.82	8.62	7.16	8.88	7.51	11.71	9.35	7.93	7.09	7.18	9.05	9.21	5.90	6.86	8.45	8.75
pH	7.99	8.11	8.20	8.03	8.10	7.97	7.73	7.72	8.54	8.20	8.23	8.21	8.01	8.08	8.16	8.10	8.07	7.92	8.07
E. coli (E. coli/100 mL)	345	535	410	540	255	685	250	285	2620	1160	950	900	850	885	395	2240	815	970	775
Hg (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Al (µg/L)	29	26	33	38	46	29	42	42	55	460	110	160	200	60	68	110	130	310	69
Cd (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.16	ND	ND	ND	ND	ND	ND
Ca (mg/L)	93	96	100	100	99	100	110	100	73	55	55	51	47	53	46	59	54	120	120
Cr (µg/L)	ND	ND	ND	0.53	ND	ND	1.3	ND	ND	0.96	ND	ND	0.67	ND	ND	ND	ND	1.1	ND
Cu (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.1	ND	ND	3.1	ND	ND	ND	ND	4.2	2.9
Fe (µg/L)	280	230	220	430	470	350	2000	530	120	950	150	250	360	81	81	730	350	1300	550
Pb (µg/L)	ND	ND	ND	ND	ND	ND	ND	ND	1.8	1.5	ND	ND	ND	ND	ND	ND	ND	4.2	ND
Mg (mg/L)	14	14	18	17	18	15	16	15	14	11	11	9.6	9.4	10	8.6	11	9.8	21	21
Mn (µg/L)	94	79	22	91	150	84	260	180	26	77	14	17	34	9.3	25	130	73	330	69
Ni (µg/L)	1.1	ND	ND	1	1	0.99	1.4	1.4	ND	1.8	ND	ND	ND	ND	1	ND	ND	4.1	2.9
Zn (µg/L)	2.7	2.7	2.5	5.9	6.7	5.4	24	91	5.3	17	4	4.6	4.3	2.4	2.1	3.3	8.5	22	6.6
Ammonia (mg/L)	0.12	0.093	0.098	0.066	0.16	0.19	0.9	0.36	0.14	0.1	0.12	0.069	0.1	0.076	0.088	0.13	0.061	0.29	0.13
COD (mg/L)	21	24	23	21	29	30	42	33	51	27	16	19	24	17	15	16	17	30	36
Oil and Grease (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.3	ND	ND	ND	ND	ND	ND	ND	ND	ND
Turbidity (NTU)	1.7	1.4	1.4	2.4	2.6	2.6	14	2.8	6.8	2.9	1.5	3.1	12	0.84	0.94	4	7.4	4.1	3.8
Nitrate/Nitrite (mg/L)	0.54	0.51	0.82	1	0.68	1.6	1.3	1.6	0.7	0.62	0.66	0.76	0.36	0.74	0.74	0.46	1.6	0.75	0.87
Chloride (mg/L)	150	150	170	170	120	270	330	240	130	79	82	69	51	73	66	46	100	200	220

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Appendix D. 2012 Preseque Isle Bay tributary water quality data (*continued)*

	Site																		
Parameter	SR0	SR1	CC1	CC2	CC3	CC4	CC5	CC6	MC0	MC1	MC2	MC3	MC4	MC5	MC6	MC7	MC8	GRO	GR1
Sulfate (mg/L)	55	53	73	74	77	54	48	49	46	29	29	25	27	30	25	30	28	110	120
Orthophosphate (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Alkalinity (mg/L)	230	230	220	220	210	250	260	260	170	140	150	150	140	140	140	170	150	230	220
TDS (mg/L)	560	510	610	590	500	710	830	700	460	290	300	280	250	300	260	230	330	720	770
TSS (mg/L)	2.4	2.8	ND	ND	3.6	ND	19	ND	5.2	13	2.4	4	4	ND	4	30	18	2.8	6
BOD5 (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	7.6	3.4	1.8	3	ND	ND	ND	3.3	ND	ND	ND
TOC (mg/L)	3.1	2.8	2.3	2.3	1.8	3.3	3.2	2.5	5.9	5.3	4.4	6.1	6.4	3.7	3.1	5.4	4.4	5.5	5.1
TN (mg/L)	0.54	0.51	0.82	1	0.68	1.6	1.3	1.6	0.7	0.62	0.66	0.76	0.36	0.74	0.74	3.3	1.6	0.75	0.87
TKN (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TP (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P as PO_4 (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

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