Presque Isle Bay Area of Concern

Screening-Level

Ecological Risk Assessment

Erie, Pennsylvania

Prepared for:
Pennsylvania Department of Environmental Protection
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LIST OF ABBREVIATIONS

AOC	Area of Concern
BUI	Beneficial Use Impairment
COPCs	chemicals of potential concern
CSM	conceptual site model
CSOs	combined sewer overflows
ERA	ecological risk assessment
ESB-TUs	equilibrium sediment benchmark- toxic unit
GLNPO	Great Lakes National Program Office
GLWQA	Great Lakes Water Quality Agreement
HQ	hazard quotient
IJC	International Joint Commission
LOAEL	lowest observable adverse effects level
mg/kg/d	milligram chemical per kilogram body weight per day
ND	Not Detected
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observable adverse effects level
PA DEP	Pennsylvania Department of Environmental Protection
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEC	probable effects concentration
PEC-Q	probable effects concentration quotient
PIB	Presque Isle Bay
SEM AVS	simultaneously extracted metals/ acid volatile sulfides
SEM-AVS/foc	simultaneously extracted metals/ acid volatile sulfides/ fraction of organic carbon content of sediment
SLERA	screening-level ecological risk assessment
SSOs	Sanitary sewer overflows
SQV	sediment quality value
TECs	toxic effects concentration
TOC	total organic carbon
TRV	toxicity reference value
USEPA	U.S. Environmental Protection Agency

EXECUTIVE SUMMARY

In 1991, Presque Isle Bay (PIB) became the 43rd and final Area of Concern (AOC) listed under the Great Lakes Water Quality Agreement. The listing was primarily driven by observations of external fish tumors on bullhead collected within the Bay. Unfortunately, addressing the fish tumors or other deformities BUI directly within the PIB AOC, as well as AOCs across the Great Lakes has proved to be challenging. The scientific understanding of the cause and effect relationships for fish tumors is complicated and confounding, and there is a lack of specific assignments of control sites, and lack of clear definitions of tumor types and background rates. As such, the data collected on fish tumors have created more questions than answers for assessing fish tumor conditions. This lack of understanding the cause-effect relationship between legacy contaminants and fish tumors has complicated the ability of AOC partners and researchers to define attainable targets for this BUI. Thus, PA DEP and its partners have opted to use the ecological risk assessment approach to evaluate contaminant risks to the PIB ecosystem. The presence and frequency of tumor occurrence is one line of evidence in the assessment of risks to fish. The ERA was designed to address the following question, originally posed by Diz (2002):

Do legacy contaminants (contaminants of potential concern) continue to pose a risk to ecosystem receptors within Presque Isle Bay?

A screening-level ecological risk assessment (SLERA) was prepared following the using the ecological risk assessment (ERA) approaches for Presque Isle Bay (PIB). The SLERA used existing collected data and combined the findings of previous studies with SLERA evaluations to understand the potential risks that concentrations of the contaminants of potential concern (COPCs) pose to the ecosystem. For the purpose of the PIB SLERA, evaluations focused on ecological components most likely affected by sediments containing COPCs. The ecological evaluations within PIB were represented by the stakeholder-developed ecosystem objectives, supporting questions and attainment targets (PA DEP 2006):

- Maintain and protect the benthic invertebrate community
- Maintain a quality fishery
- Protect and improve the near-shore habitat (to support aquatic-dependent wildlife)

The evaluation of the target objectives conducted for this SLERA was conducted using the available data to establish a weight of evidence examining the risk to ecosystem receptors. The weight of evidence concluded:

1) Surface sediment COPCs appear to be the primary chemical stressor in this system, although habitat (substrate) and invasive species may be additional stressors on the ecological community that may be challenging to tease apart.

2) The potential risk of COPC exposure benthic invertebrates across PIB are generally low based on whole sediment toxicity tests. Isolated areas may pose a moderate to high risk of exposure.

3) Benthic invertebrate exposure risk has decreased through time and are generally meeting toxicity targets.

4) The probable effect concentration (PEC) targets are generally met across PIB for most COPCs. Exceedences do occur for metals like barium and cadmium and for some PAHs. Studies focused on high concentration areas tend to exceed PEC in most cases but skew the baywide results.

5) Metals bioavailability across the PIB appears to be decreasing through time, with recent samples meeting low toxicity thresholds.

6) The quality fishery objective within PIB are supported by good water quality, a low risk of prey base (benthic invertebrates) exposure to COPCs, and fish tissue concentration of monitored compounds that are similar to background levels.

7) Water quality conditions are based on qualitative evaluations and fish tissue concentrations for monitored contaminants (e.g., mercury and PCBs) and are similar to or better than other Lake Erie levels.

8) Near-shore sediment habitats suggest that ingestion exposure risks to wildlife are moderate to low, and the elevated surface sediment concentrations of PAHs and metals (dry weight) in PIB tend to be in the vicinity of the docks and shipping channel.

Overall, it appears that the sediment targets supporting the PIB ecosystem are being met. Gaps in data to definitively describe all targets and metrics exist, but the current weight of evidence suggests that the COPC risk to ecosystem receptors within PIB is improving through time currently rates low to moderate risk.

1. INTRODUCTION AND BACKGROUND

This report presents a screening-level ecological risk assessment for Presque Isle Bay (PIB), located in Erie, PA. PIB was listed as a Great Lakes Area of Concern (AOC) in 1991as a result of two Beneficial Use Impairments (BUIs) that were identified related to contaminants in sediments: 1) restrictions on dredging; and 2) presence of fish tumors. Since 1991, several investigations and studies have been conducted by the Pennsylvania Department of Environmental Protection (PA DEP), federal agencies, and academic researchers to characterize contaminants in sediments and their potential effects on benthic fauna and fish. The studies indicated that the historical contaminant sources to PIB were largely addressed, and that concentrations of contaminants in surficial sediment and the incidence of tumors in fish were declining over time. As a result, in 2002 the AOC was designated as being “In Recovery,” and Monitored Natural Recovery was determined to be the most cost-effective remedial alternative to address residual contamination. In 2006, the restriction on dredging BUI was removed, leaving the BUI of tumors in fish as the only remaining identified impairment.

The USEPA Great Lakes National Program Office (GLNPO) and PA DEP are currently assessing whether PIB has sufficiently recovered to remove the remaining BUI and delist the AOC. To support that assessment, GLNPO contracted LimnoTech to review the site data and perform an screening-level ecological risk assessment of PIB. Gannon University was concurrently contracted to perform a human health risk assessment of PIB. This report presents the results of the ecological risk assessment (ERA). This ERA is considered to be a screening-level ERA, largely because the historical studies were designed to address specific objectives of each individual study and not designed to support a comprehensive ERA. As a result, data and information regarding some ecological exposure pathways and endpoints are not available. The assessment presented herein, however, provides a complete summary of the existing data and evaluations of the implications for ecological risks, and will help inform risk management decisions by EPA and PA DEP.

1.1 PROJECT AREA DESCRIPTION

Presque Isle Bay (PIB) is located adjacent to Erie, PA, in northwestern Pennsylvania on the southern shore of Lake Erie (Figure 1). Presque Isle Bay is 7.3 km long and 2.4 km across at its widest point, and has an average depth of approximately 4 meters. Its drainage basin includes much of the City of Erie, as well as parts of Mill Creek, Summit, Greene, and Harbor Creek Townships. The PIB watershed consists of the Bay itself, Mill Creek watershed (including Garrison Run), Cascade Creek watershed, Scott Run watershed, and the aquatic habitats (including ponds) within Presque Isle State Park.

The Bay is formed by Presque Isle, 11.3 km long sand spit. The eastern end of the Bay connects to Lake Erie through a narrow channel. This channel is dredged to allow commercial shipping traffic and recreational boaters to enter the PIB from the lake. Presque Isle State Park borders the northern edge of the Bay. Presque Isle comprises primarily sand and glacial sediments, with a series of ponds and lagoons representing the principal aquatic habitats. Presque Isle supports a diversity of wildlife, with over 320 bird species, 47 mammal species, and 30 amphibian and reptile species. Many of these species are included on Pennsylvania's list of Species of Special Concern.

Figure 1.1 Presque Isle Bay, risk assessment project area.

1.2 HISTORY

The waterfront of Erie, PA, has historically been dominated by heavy industry and commercial developments. For many years, discharges from industry and commercial developments were released directly into PIB or were directed to the City of Erie’s wastewater treatment, collection, and conveyance system. During periods of elevated runoff, untreated industrial, commercial, and residential wastewater escaping from combined sewer overflows (CSOs) were discharged to the Bay. While recent efforts to control contaminant sources have been effective in reducing discharges, historical releases resulted in substantial loadings of sediment-bound contaminants. Some of the pollutants released to PIB have decayed through natural biodegradation processes; however, substances like heavy metals and more persistent organic contaminants remain in the sediment (PA DEP 2002).

Several studies have been conducted over the past 20 years to evaluate sediment quality conditions in and across PIB. The results of these investigations show that Bay sediments contain measurable concentrations of a variety of chemicals of potential concern (COPCs), including polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), organochlorine pesticides (e.g., chlordane, DDTs), and several other substances. No impairments to the water column were indicated, but the presence of such chemicals in aquatic sediments represents a potential environmental concern (PA DEP 2002) for reasons including:

- Bed sediments provide essential and productive habitats for communities of sediment-dwelling organisms, including epibenthic and infaunal organisms;
- Sediment-dwelling organisms are important elements of freshwater ecosystems, representing important sources of food for many fish and other wildlife species;
- The presence of sediment-associated contaminants in freshwater ecosystems can be harmful to sediment-dwelling organisms, fish, and aquatic-dependant wildlife species; and,
- Certain sediment-associated contaminants can accumulate to high concentrations in the tissues of aquatic organisms and, as a result, pose a potential hazard to those species that consume aquatic organisms, including wildlife and humans.

In 1991, Presque Isle Bay became the 43rd and final Area of Concern (AOC) listed under the Great Lakes Water Quality Agreement (GLWQA). The listing was primarily driven by observations of external fish tumors on bullhead collected within the Bay, and reported to U.S. Fish and Wildlife Service at that time (PA DEP 2006).

Based upon a limited analysis of the existing data, sediment contamination and tumors in brown bullheads were the biggest AOC concerns. Regarding pollutants of concern, work on both sediments and brown bullheads indicated that PAHs could be of greater concern than the heavy metals. The main source for the contaminants appeared to be in-place sediments, as no correlation was found between water and sediment contaminant concentrations (PA DEP 1992).

From these assessments, PA DEP believed that two of the 14 beneficial uses were potentially present in the Bay: (1) fish tumors and other deformities, and (2) restrictions on dredging activities. Following an impaired uses evaluation, the only pollutants of concern identified were sediment-bound contaminants. No water column impairments were indicated. Fish impairments, if environmentally caused, were believed related to the sediment contamination; however, no correlation was made between sediment contamination and tumor rates (PA DEP 1992).

Between 1991 and 2006, the extensive efforts of PA DEP and its partners culminated with the removal of the dredging BUI, as documented in the removal petition and detailed rational described in the 2006 PA DEP report, *Delisting Restrictions on Dredging Activities Beneficial Use Impairment in the Presque Isle Bay Area of Concern* (PA DEP 2006).

A number of factors were taken into consideration when evaluating removing the dredging beneficial use impairment for Presque Isle Bay. Contaminants were detected in the sediment at concentrations greater than sediment quality guidelines associated with increased toxicity to benthic organisms; however, when the overall contamination was considered, none of the whole-sediment samples exceeded levels linked with reduced survival or growth of benthic organisms. Also, it was found that levels of measured contaminants in sediments were not sufficient to adversely affect fish and aquatic-dependent wildlife in the AOC. For bioaccumulative compounds, fish tissue data indicate that PIB sediments are not a significant source—concentrations of mercury and PCBs in tissue from Presque Isle Bay fish were similar to those found in Lake Erie fish, indicating a lake-wide rather than AOC-specific problem.

The evaluation of sediment quality in the Bay indicated that factors other than the contaminants in the sediment might be contributing to the limited toxicity to benthic organisms that was observed. Analysis of the data shows that metals and PAHs, while present, did not or rarely occurred in the AOC or study area sediments at concentrations sufficient to adversely affect benthic organisms, fish, or aquatic-dependent wildlife. Ecosystem health targets were being met in the AOC, and there was no evidence that the moderate level of contamination found during sediment studies was responsible for degrading the ecosystem.

Finally, given that the only "restriction" on dredging activities was regulatory, and that sediment from any location within the AOC met those requirements, it was recommended that the dredging beneficial impairment be removed (PA DEP 2006).

The extensive and combined efforts described above resulted in the delisting of the restrictions on dredging activities BUI, leaving one remaining BUI within the PIB AOC—fish tumors or other deformities.

1.3 ERA PROBLEM STATEMENT

The presence of fish tumors is considered a beneficial use impairment when, "the incidence rate of fish tumors or other deformities exceeds rates at unimpacted or control sites, or when survey data confirm the presence of neoplastic or pre-neoplastic liver tumors in bullhead or suckers" (IJC 1991). Unfortunately, addressing the fish tumors or other deformities BUI directly within the PIB AOC, as well as AOCs across the Great Lakes, has proved to be challenging (Rafferty et al. 2009). The scientific understanding of the cause and effect relationships for fish tumors is complicated and confounding, and there is a lack of specific assignments of control sites, and lack of clear definitions of tumor types and background rates. As such, the data collected on fish tumors have created more questions than answers for assessing fish tumor conditions (Rafferty et al. 2009). Section 3.4.4 provides a summary of the state of the science, citing recent publications, and existing challenges that remain in addressing the IJC (1991) definition of impairment, with respect to understanding causes or incidences of tumors on sentinel indicator species such as brown bullhead (*Ameiurus nebulosus*). Further, there is no information to indicate that the presence of tumors on fish adversely impacts their survival, growth, or reproduction, or poses a threat to ecological predators of those species.

The state of the science and the lack of understanding of cause-effect relationships have complicated the ability of AOC partners and researchers to define attainable targets for this BUI (Rafferty et al. 2009). Thus, PA DEP and its partners have opted to use the ERA approach, using existing information. The presence and frequency of tumor occurrence is one line of evidence in the assessment of risks to fish. The ERA was designed to address the following question, originally posed by Diz (2002):

Do legacy contaminants (contaminants of potential concern) continue to pose a risk to ecosystem receptors within Presque Isle Bay (Diz 2002)?

1.4 REPORT SCOPE

The PIB SLERA included an extensive report evaluation and data review of documents provided by PA DEP and its partners. The data and information are synthesized and summarized to support the development of a detailed conceptual site model (CSM) for identified contaminants of potential concern (COPCs) within PIB. The model uses existing information to identify pathways of exposure and ecosystem receptors at potential risk. Where available and appropriate, existing data have been examined, assessed and summarized to support risk assessments for ecosystem receptors including benthic invertebrates, fish, and wildlife. The evaluation culminates with a qualitative weight-of-evidence evaluation that assesses the likelihood that COPCs pose unacceptable risks to ecosystem receptors. A summary of findings, uncertainties, and conclusions is also included in this report.

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2. PROJECT APPROACH

2.1 OVERVIEW

In response to the challenges of defining clear targets that lead to delisting for the fish tumor and other deformity BUI in PIB, PA DEP and its AOC partners have opted to pursue a screening-level ecological risk assessment approach (SLERA). The SLERA process is commonly used to systematically evaluate how likely it is that adverse ecological effects might occur as a result of exposure to stressors (USEPA 1998). Ecological risk assessments can be prospective and used as a prediction of the likelihood of future effects or current as an evaluation of the likelihood that observed effects are associated with current exposure to stressors (Gala et al. 2009). The PIB SLERA process evaluates and assesses risk of chemicals of potential concern (COPCs) within the Bay and whether their concentrations pose a significant risk to receptors in the ecosystem.

2.2 RISK ASSESSMENT FORMAT

The ecological risk assessment for Presque Isle Bay generally follows EPA guidance for conducting baseline ecological risk assessments under the Comprehensive Environmental Response, Compensation, and Liability Act (EPA 1998). In addition, the framework provided by Cura et al. (2001) was followed as it was specifically developed for PAH-contaminated sediments, such as those found in PIB. However, comprehensive ERAs performed under the EPA guidance are typically iterative investigations specifically designed to meet ERA data quality objectives established prior to conducting the investigations to assess all potential significant and complete exposure routes and receptors potentially at risk from exposure to COPCs at a site. This ERA relies on data readily available with no new data collection to fill data gaps. The supporting data were collected as part of several independent historical investigations that were not specifically designed to support a formal and comprehensive ERA. While the ERA presented herein is more detailed than and goes beyond the objectives of a typical screening level ERA, it is considered to be a SLERA. This assessment uses a mix of previously developed assessments (published and unpublished), conclusions, and recommendations combined with components of analysis of the best available datasets and estimation methods to develop a weight-of-evidence evaluation of risk to ecosystem receptors within the AOC, for those COPCs, pathways and receptors where data are available.

The PIB ERA addresses the four primary components used in the assessment of ecosystem risk (EPA 1998; Cura et al. 2001). A fifth component is included that summarizes the findings, identifies uncertainties, and conclusions based on the ERA. The ERA components include the following:

> *Problem Formulation.*
> The Problem Formulation includes defining the objectives, developing the conceptual site model (CSM), identifying COPCs, selecting and characterizing receptors, and identifying the endpoints of the assessment

(USEPA 1992). The key components of problem formulation are detailed in Section 2.1.1, based on existing documents and evaluations.

Based upon the objectives and the CSM, three ecosystem receptor groups were identified for assessing risks, including benthic invertebrates, fish, and wildlife. Risk assessments were conducted for each of these receptor groups, and consisted of the following components:

Exposure Assessment.
The Exposure Assessment estimates the magnitude of actual and/or potential ecological exposure to a contaminant of concern, the frequency and duration of exposure, and the pathways of exposure. For the PIB SLERA, COPC concentrations measured in sediments served as the primary basis for the quantitative exposure assessments. Data for other exposure media (e.g., water column, pore water, food web) were not available and so were either estimated through exposure models or qualitatively characterized.

Effects Assessment.
The Effects Assessment summarizes and weighs available evidence regarding the potential for contaminants to cause adverse effects in exposed organisms, and estimates the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. The effects assessments for the PIB SLERA relies primarily on published toxicity reference values (TRVs), sediment quality values (SQVs), and whole-sediment toxicity tests.

Risk Characterization.
The Risk Characterization summarizes and integrates the Exposure Assessment and Effects Assessment into a quantitative and qualitative expression of risk, supporting the weight-of-evidence conclusions of ecosystem effect. The benthic invertebrate risk assessment relied primarily on comparison of COPC concentrations in sediments with consensus based SQVs and site specific sediment toxicity tests. The fish risk assessment relied primarily on general conclusions of prior investigations of water quality, and available measured tissue concentrations of bioaccumulative chemicals. The wildlife risk assessment relied on estimated exposure and uptake model results compared with TRVs.

Uncertainties and Conclusions.
Finally, an overall summary of the risk assessments for the three receptor groups is provided in Section 4 and includes a characterization of uncertainties and presents conclusions.

2.3 PROBLEM FORMULATION

The problem formulation step provides background to conduct the screening-level risk assessment to determine if chemicals of potential concern within the Bay pose a significant risk to receptors in the ecosystem. Many of the problem formulation components required for this phase of the ERA were captured and defined by the extensive efforts of the AOC partners and summarized in the delisting documentation for removing the restriction on dredging BUI (PA DEP 2006). That is, much of the effort included in, *The Delisting of the Restrictions on Dredging Activities Beneficial Use Impairment in the Presque Isle Bay Area of Concern* (PA DEP 2006), focused on defining ecological receptors and ecosystem components, and thus present a robust framework for defining and directing the assessment of ecosystem risk within the PIB AOC.

2.3.1 Risk Assessment Objectives for PIB

The PIB ERA risk assessment objectives were developed to be consistent with the PIB ecosystem objectives developed by PA DEP (2006) for sediment COPCs. The ecosystem objectives in PIB (PA DEP 2006) include the following:

1. Protect and preserve recreational uses;
2. Maintain and protect the benthic invertebrate community;
3. Maintain a quality fishery;
4. Protect and improve the near-shore habitat;
5. Maintain the aesthetic qualities (e.g., prevent algal blooms, unpleasant odors, visual impairments, etc.);
6. Maintain and improve water quality conditions; and
7. Eliminate the restrictions on dredging.

For the purpose of the PIB screening-level ecological risk assessment, evaluations will focus on ecological components of concern in the system most likely affected by sediments containing COPCs. Thus, the ecological evaluation within PIB is best represented by the stakeholder-developed ecosystem objectives (Objectives 2-4 from above), supporting questions and attainment targets (PA DEP 2006):

- <u>Maintain and protect the benthic invertebrate community</u>
  1) Are the levels of contaminants in whole sediments from Presque Isle Bay greater than benchmarks for the survival or growth of benthic organisms?
  2) Is the survival or growth of benthic organisms exposed to whole sediments from Presque Isle Bay significantly lower than that in control or reference sediments?

- <u>Maintain a quality fishery</u>
  1) Are the levels of contaminants in water and whole sediments from Presque Isle Bay greater than benchmarks for the health of fish?
  2) Are the levels of contaminants in fish tissues from Presque Isle Bay greater than the levels of contaminants in fish from elsewhere in Lake Erie?

- Protect and improve the near-shore habitat (to support aquatic-dependent wildlife)
  1) Are the levels of contaminants in whole sediments from the Presque Isle Bay near-shore environments greater than benchmarks for the health of aquatic-dependent wildlife?

2.3.2 Conceptual Site Model

The purpose of the CSM is to describe the sources of COPCs, routes of transport, media, routes of exposures, and ecological receptors (Suter 1996). The model framework for PIB includes sources, routes of transport from contaminated media (sediment), routes of exposure of receptors to media, and endpoint receptors initiated by PA DEP (2006). Following Suter (1996), the CSM for the PIB ecosystem as depicted in MacDonald (2008) has been expanded to identify specific sources, COPC transfer paths, sediment processes that may contribute to COPC transfer, and specific receptors identified in PIB and other supporting documents (Figure 2.1). The important components of the CSM are described below.

Chemicals of Potential Concern - Identification of COPCs represents an essential element of the overall sediment quality assessment process (USEPA 1998). The COPC list and associated sources stem from several evaluations specifically conducted to assess PIB AOC conditions (MacDonald 2008). For the PIB model, only the toxic COPCs that partition into sediments were considered, and COPCs that usually (90% or more) or always occurred at levels below analytical detection limits were eliminated from further consideration (MacDonald 2008). Thus, the COPCs evaluated in PIB ERA were selected because of their frequency of exceeding toxicity thresholds (probable effect concentration (PEC)) in surficial sediment samples, as identified by MacDonald (2008). PECs are sediment quality guidelines established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (EPA 2000). Adverse effect documentation is complex and includes uncharacterized chemicals or stressors, localized conditions of bioavailability, movement of organisms, responses of organisms, and representation of unsampled areas and errors in chemical and biological responses (Simpson et al. 2005).

Table 2.1 describes the COPCs (MacDonald 2008) included in the PIB model and SLERA.

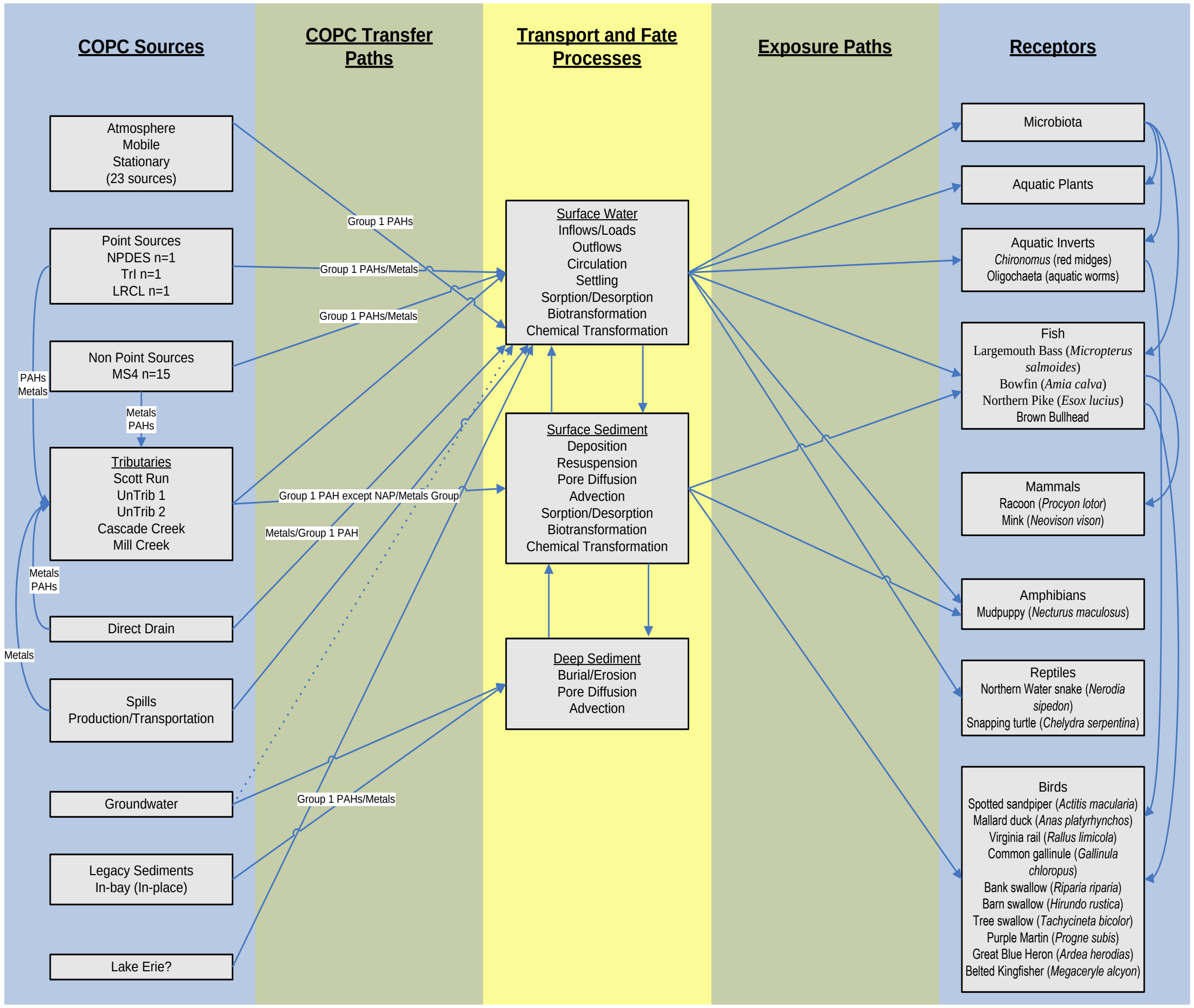

Figure 2.1 Conceptual site model (CSM) for Presque Isle Bay sediment processes across the Bay. The CSM includes the COPC sources, sediment processes and potential receptors within the Bay

Table 2.1. COPCs within PIB with more than 10% exceedance of selected toxicity levels (MacDonald 2008).

Chemical of Potential Concernt (COPC)	Selected Toxicity Threshold (PEC)	Exceedance in PIB study area	Bioaccumulative[1]	Source
Metals (mg/kg DW)				
Antimony	25	43% (6 of 14)		MacDonald (2008)
Arsenic	33	22% (29 of 131)		MacDonald (2008)
Barium	60	66% (80 of 121)		MacDonald (2008)
Cadmium	4.98	45% (56 of 125)	Y	MacDonald (2008)
Lead	128	29% (41 of 141)	Y	MacDonald (2008)
Nickel	48.6	34% (47 of 140)		MacDonald (2008)
Zinc	459	11% (16 of 141)		MacDonald (2008)
Polycyclic Aromatic Hydrocarbons (PAHs; µg/kg DW)				
Acenaphthene	88.9	45% (15 of 33)		MacDonald (2008)
Acenaphthylene	128	31% (12 of 39)		MacDonald (2008)
Benz(a)anthracene	1050	25% (16 of 63)		MacDonald (2008)
Benzo(a)pyrene	1450	17% (11 of 63)		MacDonald (2008)
Chrysene	1290	25% (16 of 63)		MacDonald (2008)
Dibenz(a,h)anthracene	135	51% (20 of 39)		MacDonald (2008)
Fluoranthene	2230	26% (17 of 65)		MacDonald (2008)
Phenanthrene	1170	19% (12 of 63)		MacDonald (2008)
Pyrene	1520	59% (37 of 63)		MacDonald (2008)

[1] accumulation of chemicals in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water, sediment, and pore water in the sediment." – US EPA 2000

Sediment Processes – Diz (2002) described the surficial sediment samples as dominated by fine sediments such as sand, silt, and clay. After discarding zebra mussel shells found in sediment samples at some locations, the average composition of the sediments sampled in 2000 consisted of 16.5% sand, 42.8% silt, and 40.8% clay. Although the samples were spatially varied across the Bay, they are assumed to represent the general sediment composition of PIB surficial sediment conditions.

Analysis of chemical concentrations in whole-sediment samples serve as a simple and common method for estimating risk of exposure from COPCs. However, physical and chemical properties of sediments vary from site to site and affect the bioavailability of the chemicals to exposed receptors. As such, measured COPC concentrations in one sample may have a very different effect than the same concentrations measured in a different sample. Chemicals of concern in PIB such as PAHs are hydrophobic and tend to immediately adsorb (bind) to fine sediments and organic carbon in the sediment matrix (Fuchsman et al. 2001). In addition, different types of organic carbon have different adsorption properties; for example, "black" carbon adsorbs hydrophobic chemicals more highly and irreversibly than carbon from detritus. Metal

COPCs' bioavailability is also controlled by processes such as: 1) speciation (e.g., metal binding with particulate sulfide, organic carbon, and iron hydroxide phases); 2) sediment–water partitioning relationships; 3) organism physiology (e.g., COPC uptake rates from surface and pore water particles); and 4) organism behavior (e.g., feeding on organisms exposed to COPCs and other sediment disturbing behaviors) (Simpson and Batley 2006; Fuchsman et al. 2001).

Measures of sediment concentrations for COPCs can provide an indication of relatively long-term environmental exposures. The risk of exposure to organisms in waterbodies with hydrophobic COPCs depends on the factors described above. Organic carbon is a critical factor controlling the availability of PAHs and metals in sediment and effect on aquatic organisms (USEPA 2000; Simpson and Batley 2006). Physiochemical processes like temperature increase the solubility and organism uptake potential of hydrophobic COPCs, while increases in salinity decrease the solubility of such compounds. Finally, the behavior of species within COPC waterbodies can affect the potential for exposure. For example, the behavior of some bottom-dwelling fishes can result in the resuspension of sediment-bound chemicals, thus increasing the risk of exposure.

However, because fish metabolize chemicals like PAHs, it remains a challenge to scientists to establish adverse sediment exposure and injury to these organisms, and thus the organisms that feed on fishes themselves (Fuchsman et al. 2001).Upon release into aquatic ecosystems, COPCs partition into the water and sediment, depending on their physical and chemical properties and the characteristics of the receiving waterbody (PA DEP 2006). Aquatic organisms may be exposed to the COPCs in the water or sediment, so the CSM attempts to represent sediment transport processes operating in the ecosystem (Suter 1996; ITRC 2011). That is, the model depictions identify pathways and sources of bioavailability operating within the system (ITRC 2011). The exposure pathways for COPCs were developed using PIB documents such as PA DEP (2006) and MacDonald (2008), as well as general guidance documents such as ITRC (2011).

The PIB AOC is currently listed as "In Recovery." The natural capping of contaminated Bay floor areas with inputs of "cleaner than in the past" sediments supplied from watershed is considered a likely solution to the Bay's contaminated sediments issue (PA DEP 2006). Foyle and Norton (2006) suggests that the complex nature of the sediment transport conditions in PIB includes a mix of resuspension of legacy COPCs in shallow zones and deposition in deeper areas, and that inputs from outside sources have highly variable deposition rates, where deposition processes dominate. The variability in the deposition rates across the Bay may require several decades to reduce the physical availability of COPCs in the system (Foyle and Norton 2006). Foyle and Norton's (2006) evaluation of the sediment processes in PIB for COPCs helped refine the ecological receptor list below (Table 2.2).

Receptors – The purpose of including ecological receptors in the model is to depict how exposure from COPCs may occur to organisms of concern (Suter 1996). There are a wide variety of ecological receptors that could be exposed to contaminated sediment in Presque Isle Bay. The aquatic organisms that occur in the Bay are numerous and include microbiota (e.g., bacteria, fungi and protozoa), aquatic plants, aquatic invertebrates, fish, amphibians, reptiles, bird and mammals. A specific list of key indicator organisms was developed in collaboration with PA DEP (personal communications, Jim Grazio 2011) to refine the risk evaluation (Table 2.2).

Table 2.2. Presque Isle Bay list of primary ecological receptors of concern (PA DEP 2011)

Group	Species
Invertebrates	
	Chironomus (red midges)
	Oligochaeta (aquatic worms)
Fish	
	Largemouth Bass (*Micropterus salmoides*)
	Bowfin (*Amia calva*)
	Northern Pike (*Esox lucius*)
Birds	
Sediment-Probing	Spotted sandpiper (*Actitis macularia*)
	Mallard duck (*Anas platyrhynchos*)
	Virginia rail (*Rallus limicola*)
	Common gallinule (*Gallinula chloropus*)
Insectivorous	Bank swallow (*Riparia riparia*)
	Barn swallow (*Hirundo rustica*)
	Tree swallow (*Tachycineta bicolor*)
	Purple Martin (*Progne subis*)
Carnivorous Wading	Great Blue Heron (*Ardea herodias*)
Mammals	
	Racoon (*Procyon lotor*)
	Mink (*Neovison vison*)
Reptile	
	Northern Water snake (*Nerodia sipedon*)
	Snapping turtle (*Chelydra serpentina*)
Amphibian	
	Mudpuppy (*Necturus maculosus*)

Using existing studies and data, the PIB CSM can be used to identify the source, pathway, and receptors that are best and least understood within the PIB AOC.

For the PIB SLERA, the list of ecological receptor groups was refined to three groups (benthic invertebrates, fish, and wildlife (mammals and birds)) based upon the availability of data and published TRVs. Exposure routes and effects are different for each of these groups, so separate risk assessments were performed for each. Representative species within each group were used in each risk assessment to estimate exposure and effects and to characterize the risks to each group.

2.3.3 Assessment Endpoints

EPA (1992) defines assessment endpoints as explicit statements of the ecological systems that are to be protected. General considerations for selecting assessment and measurement endpoints include ecological relevance, policy goals and societal values, and susceptibility to chemical stressors (EPA 1992; 1996). The ecosystem objectives and endpoints developed from the extensive efforts of PA DEP and its partners in, *The Delisting of the Restrictions on Dredging Activities Beneficial Use Impairment in the Presque Isle Bay Area of Concern* (PA DEP 2006), are appropriate as a foundation for the PIB SLERA.

Consistent with the CSM presented above and the PA DEP endpoints, the assessment endpoints for the purposes of this SLERA include survival, growth, and reproduction of: 1) benthic invertebrates, 2) fish, and 3) wildlife (mammals and birds). Representative receptors, measurement endpoints and target metrics, and lines of evidence are presented below for each of these ecosystem receptor groups. Multiple lines of evidence and targets were evaluated where data were available and then compiled and collectively assessed under a qualitative weight-of-evidence assessment approach.

Weight-of-evidence is a process by which multiple lines of evidence, often expressed as measureable endpoints (targets), are related to assessment endpoints (objectives) to evaluate whether significant risk is posed to the environment (Menzie et al. 1996). Because the PIB SLERA is relying on existing studies and findings supported by limited independent data evaluation, the weight-of-evidence approach relies heavily on the data and findings of previously conducted studies. The PIB SLERA approach uses endpoints interpreted from the PIB studies combined with data assessments described in Section 3 to evaluate targets that support SLERA objectives. The results of the combined sets of evaluations are used as the qualitative weight-of-evidence assessment to describe objective attainment. The qualitative approach is applied because the SLERA is using a mix of studies whose approach, targets, and purposes were not always directly comparable. The assessment endpoints for each of the three ecosystem receptor groups for the SLERA are discussed below.

2.3.3.a Benthic Invertebrate Assessment Endpoints, Objectives and Targets

As described in Section 2.3., an ecosystem objective for PIB is to maintain and protect the benthic invertebrate community. Target metrics to assess the growth survival and reproduction of benthic invertebrates for the SLERA were developed using published sediment quality guidelines as a relatively simple, conservative calculation of toxicity threshold and are consistent with targets presented in PA DEP (2006). However, as discussed above, this simple comparison of sediment chemistry SQVs may not adequately account for reduced site-specific bioavailability. As such, the weight-of evidence sediment quality triad approach was used. The approach integrates sediment chemistry, sediment toxicity testing and macroinvertebrate community analysis (ITRC 2011). Unfortunately, within PIB, no studies evaluated all components of the sediment quality triad simultaneously. Further, there are no studies that quantitatively assess the existing benthic community structure, abundance and diversity in comparison with non-impacted reference areas. However, key sediment quality components (e.g., site-specific sediment toxicity tests) and data trends can be used to help assess PIB ecosystem objectives to maintain and protect the benthic invertebrate community.

The specific targets and metrics used in the PIB SLERA for the assessment of benthic invertebrate risks include the following:

Target 1- at least 90% of the sediment samples from Presque Isle Bay have the conditions necessary to support healthy benthic invertebrate communities, as indicated by metrics in Table 2.3.

Table 2.3. Benthic invertebrate community target metrics.

Metric	Target Value
Bulk Sediment Quality Benchmarks (Median PEC-Q)	< 1.0 (ratio) and <6 PEC exceedances[1] per station (OEPA 2010)
Metals Mixtures (SEM-AVS)	< 0.0
Metals Mixtures with Organic Carbon (SEM-AVS/foc)	< 130
PAH Mixtures ESB-TUs	< 1.0
Sediment toxicity to amphipods and midges for survival and growth[2]	- Control-adjusted survival of amphipods > 75% - Control-adjusted growth of amphipods >90% - Control-adjusted survival of midges > 75% - Control-adjusted growth of midges >70%
Notes - SEM (simultaneously extracted metals); AVS (acid-volatile sulfide); foc (fraction of organic carbon); ESB (equilibrium partitioning sediment benchmarks); TU (toxicity units)	

[1] MacDonald et al. 2000. [2] Control-adjusted survival of midges >75% means that the test results must be more than 25% different from the control result to be considered toxic.

These metrics are consistent with the triad approach in that the metrics use target values to assess benthic community conditions, and rely on comparisons of sediment chemistry with SQVs as well as site-specific sediment toxicity tests. Sediment chemistry targets and toxicity tests are the main triad components available in PIB to support the weight-of-evidence determinations.

Benthic community descriptions are under-represented within PIB. Describing such targets for benthic communities in lentic environments is challenging because the structure and composition of these communities are dependent on many factors, such as physical sediment characteristics and are highly variable both spatially and temporally (Reice and Wohlenberg 1993), requiring intensive and expansive sampling efforts across the micro and macro environments within PIB, as well as among seasons and years. Grab samples of PIB sediments were described as black or brown and dominated by fine sediments, based on particle size analysis with categories of sand, silt and clay best describing the dominant substrates found in PIB samples (Diz 2002). The macroinvertebrate evaluations within PIB (Diz 2002) found samples dominated by zebra mussels (*Dreissena)*, two pollution-tolerant macroinvertebrates; segmented worms (*Oligochaetae*), and midges (*Chironimidae*), as well as moderately tolerant gastropods and amphipods.

The limited number of macroinvertebrates samples support the generally held view that accumulations in surface fine sediments lead to changes (generally reductions) in macroinvertebrate community diversity (Harrison et al. 2007) and dominated by taxa such as *Chironomidae, Oligochaeta* and *Sphaeridae* (frequently associated with fine sediments because they are able to burrow into sediments). Therefore, fine sediment covered substrates such as those within PIB, contain less diverse macroinvertebrate communities that are primarily habitat limited and dominated by taxa that are tolerant to fine sediments (Waters 1995).

PEC-Q

Sediment chemistry metrics include a number of target values. PEC-Q is the ratio of the concentration of a COPC to its probable effect concentration (PEC). The PEC-Q approach provides a direct way for determining if the concentration of COPCs impedes biological resources (MacDonald 2008). This determination can be made by comparing the measured concentrations of COPCs to acute or chronic toxicity thresholds. For this study, consensus-based PECs were used to identify the substances at concentrations high enough to affect benthic invertebrates.

To calculate toxicity of sediment, the average of the PEC-Qs in the sediment is calculated. The mean PEC-Q allows for the mixture of chemicals in the sediment to be quantified. This quantification makes it a desirable metric to report full-sediment toxicity (MacDonald 2008). Although the Mean PEC-Q is the value typically calculated using procedures established by USEPA (2000). The median (Median PEC-Q) was used here because the high standard deviations identified within PIB PEC-Q may limit the value of the arithmetic mean as an accurate estimate of central tendency, particularly when multiple areas (including random and targeted), targeted studies (targeted at COPC concentration), sample methods (multiple gear types) and processing approaches (differing QA/QCs) are being evaluated.

SEM-AVS

Simultaneously extracted metals (SEM) - acid volatile sulfides (AVS) & (SEM-AVS)/f_{OC} models were applied to PIB samples, as developed by USEPA (2005) to evaluate the toxicity of metals to sediment-dwelling organisms. The application of these models is dependent on the collection of SEM and AVS data in whole-sediment samples. The models assume that specific metals can only cause or contribute to sediment toxicity when the sum of their concentrations of copper, lead, nickel, and zinc exceed the concentration of AVS. The presence and quantity of AVS and organic carbon in sediments affects the likelihood that COPCs will affect sediment-dwelling organisms (ITRC 2011). That is, the EPA-adopted equations (EPA 2000) assume that greater concentrations of sulfides and organics in sediments results in binding of COPCs to these particulates, reducing the bioavailablity of contaminants to the ecosystem (ITRC 2011).

(SEM-AVS)/f_{OC}

Further, since metals can bind to organic carbon in sediment, the model has been updated by incorporating the fraction of total organic carbon (f_{OC}) into the model (OEPA 2010). Like AVS, the presence and quantity of organic carbon in sediments affects the likelihood that COPCs will affect sediment-dwelling organisms (ITRC 2011). It is recognized that the organic carbon content of the sediment is the component most responsible for controlling bioavailablity of organic COPCs (Adams and Rowland 2003; Burgess 2009). Thus, it is believed that the (SEM-AVS)/f_{OC} model represents a more reliable representation of the toxicity of COPCs to sediment-dwelling organisms from whole-sediment samples (Adams and Rowland 2003).

ESB-TU

Finally, equilibrium partitioning sediment benchmarks (ESB) approach was included (USEPA; 2000) because this approach predicts chemical interactions among sediments, interstitial water and COPCs. The ESB estimates direct toxicity to benthic organism and offers several advantages over other effects–based benchmarks because the calculations are contaminant-specific, address causal relationships between COPCs and their potential for toxicity, and encompass site-specific conditions that affect bioavailability (ITRC 2011). However, it should be cautioned that care should be used in interpreting ESBs in dynamic systems such as PIB. In highly erosional or depositional environments (e.g., wind, seiche, navigation), partitioning may only reach a state of near-equilibrium (EPA 2003).

PAHs tend to occur in the environment in mixtures, so assessing the toxicity of PAH mixture effects uses concept of toxic units (US EPA 2003). Toxic units (TUs) are described as the ratio of the concentration of the PAH mixtures relative to the toxic effect of the concentration. The ESB-TU method was initially developed for sediments where 34 PAHs were analyzed. However 13 or 23 PAHs are the more commonly measured combination of PAHs, so to characterize the uncertainty in the ESB-TU calculations, uncertainty factors were applied to ESB-TU values calculated within PIB as suggested by EPA (2003)

In principle, the uncertainty factor serves as a multiplier to convert TUs when less than 34 PAHs are evaluated. However, uncertainty factors are site-specific because the variability of PAHs in contaminated sediments is uniquely distributed at each site (Burgess 2009) based on the processes controlling the sediment distribution (e.g., wind, seiche, navigation, dredging) and the methods used to collect samples (e.g., within and across PIB). So uncertainty factors should only be used as a very general estimate of TU (Burgess 2009).

Sediment Toxicity Tests

Toxicity tests provide an important complement to ESB assessments in determining overall risk from COPCs (EPA 2003). Like other procedures for detecting adverse affect, toxicity tests provide value as an independent parameter of effect, but include limitations that should be considered from the results. Toxicity tests are capable of detecting any toxic chemical and are useful for detecting the combined effect of chemical mixtures, if those effects are not considered in the formulation of the applicable chemical-specific benchmark (EPA 2003). However, they only provide information on the toxicity to the species being tested. Typically, species used for toxicity tests reflect more sensitive and less tolerant benthic species (EPA 2003). Toxicity tests conducted with PIB sediments are included to provide a valuable and complementing component for interpreting the assessment of adverse affect to the biota.

Diz (2002) evaluated PIB sediment toxicity. The sediment toxicity tests, the survival of *C. tentans* was slightly lower in the PIB sediments than in the control. The growth of the organisms was both greater and less than the control for various PIB sites, but not significantly different from the control. The survival and growth of *H. azteca* in PIB sediment was not significantly different from the control. The survival of *D. magna* was more sensitive to PIB sediments with survival rates generally lower than the control and reproduction was more affected by PIB sediments when compared to the control. Finally, mouthpart deformities of chironimids was another indication of sediment toxicity tested and out of the 90 individuals tested, only one exhibited mouthpart deformities, indicating low toxicity to chirominids.

The diversity and distribution of the PIB benthic community may be limited by the dominance of fine sediments, as measured by the PIB grab samples. Systems dominated by fine sediments exert physical limits on the potential of benthic communities by reducing the density and distribution of food sources, oxygen for respiration and interstitial spaces available that support diverse habitat types (Harrison et al. 2007). Although the metrics for the health of the benthic community target are chemistry and toxicity based, the physical limits affecting the benthic community might be considered in future evaluations of benthic community health as well.

2.3.3.b Fishery Risk Assessment Endpoints, Objectives and Targets

A second ecosystem objective for Presque Isle Bay is to maintain a quality fishery. Several targets and lines of evidence were evaluated for the assessment of the conditions conducive to the survival, growth and reproduction of fish in PIB, as described below:

Target 1 - Water Quality Standards protective of Aquatic Life are met**.** EPA and Pennsylvania water quality standards and criteria for chemicals are based upon toxicity tests and are developed to be protective of aquatic life. Comparison of water quality data for the COPCs to their respective criteria would provide an assessment of potential risks or lack thereof posed by chemicals in PIB. While water samples have historically been collected and analyzed for PIB, the data from these studies were not readily available in published reports. However, the previous studies where samples have been collected concluded that the quality of the water column in PIB was good and that there was no correlation between sediment COPC concentrations and the overlying water column (PA DEP 1992).

Target 2 - At least 90% of the sediment samples from Presque Isle Bay should have benthic conditions necessary to support healthy benthic invertebrate communities to support fish communities. This is the same metric that was evaluated in the benthic invertebrate risk assessment as described above.

Target 3 - The concentrations of bioaccumulative COPCs in the tissue of fish from Presque Isle Bay are not significantly higher than the levels in fish tissues from the same species in Lake Erie.

> Analyses of COPC in fish are not available within PIB for comparison to Lake Erie species, but most of the COPCs are metabolized by fish and not bioaccumulated. PCB and Mercury are regularly assessed contaminants within PIB and the Great Lakes (including Lake Erie) and are the predominant chemicals of concern for bioaccumulation and resulting effects in Great Lakes AOCs. While these chemicals have not been identified as COPCs for PIB, PCB and mercury were used as surrogates within PIB as an indicator of PIB ecosystem exposure to bioaccumulative compounds.

Target 4 – The presence of lesions and tumors in individuals has not diminished the survival, growth and reproduction of the PIB black bullhead population:

- The Bullhead population within PIB represents a single population with little interaction outside of the bay (Millard et al. 2009) so the health of the population is likely responding primarily to internal dynamics including contaminant stressors. Pyron et al. (2001) noted that the overall health of the brown bullhead population in Presque Isle Bay has improved dramatically since 1992. Skin and liver tumor rates have decreased to background levels, the population is reproducing, and the brown bullhead population estimate appears to be stable.
- Kuehn et al. (1995) attempted to establish a correlation between PAH contaminated sediments, instances of liver pathology (although not definitively cancerous) and species diversity and densities of fishes. Kuehn et al. (1995) found that some differences among bullhead species and diversity appeared to exist, although the differences were not significant. Within PIB, no evidence to suggest that the presence of tumors are currently impacting the health, growth, survival, reproduction of fish Pyron et al. (2001).

So that in light of all risk assessment information, PIB appears to provide conditions that support the survival, growth and reproduction for fish as well as other ecosystem receptors.

2.3.3.c Wildlife Assessment Endpoints, Objectives and Targets

A third objective identified as part of protecting and improving the near-shore habitat would be to ensure that COPC concentrations do not pose unacceptable risks to wildlife, particularly birds and mammals. The following targets have been established for this assessment:

Target 1 – Exposure concentrations of COPCs in sediments and benthic fauna that serve as food sources should not pose unacceptable risks to mammals or birds.

COPC data for benthic fauna are not available within PIB. However, exposure of potential wildlife receptors to COPCs in PIB can be estimated using sediment data and ingestion exposure models. Sediment-probing birds (Table 2.2) consume mostly sediment-associated invertebrates and may incidentally ingest more sediment than birds in other feeding guilds. Accordingly, exposure of sediment-probing birds to sediment contamination is expected to be higher than exposure of other groups, such as herbivorous birds and ducks in shallow areas containing such sediments. Further, piscivorous birds and mammals have a high exposure potential to contaminants through the consumption of secondary aquatic consumers, such as invertivorous fish. Several aquatic-dependent bird and mammal species use habitats within the PIB (Table 2.2).

Target 2- The concentrations of bioaccumulative COPCs in the tissue of fish from Presque Isle Bay are not significantly higher than the levels in fish tissues from the same species in Lake Erie. Fish serve as a food source for birds and mammals in Presque Isle Bay. This is the same target as Target 3 for the fish risk assessment.

Target 3 - At least 90% of the near-shore sediment samples from Presque Isle Bay have the conditions necessary to support healthy benthic invertebrate communities to support wildlife that consume benthic invertebrates as a food source.

The evaluations for the Target 3 objectives within near-shore habitats are the same as COPC evaluations conducted to ***Maintain and Protect the Benthic Invertebrate Community***, with a focus on samples collected shallower than 2 meters deep (the finest depth resolution available in GIS within PIB).

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3. RISK ASSESSMENT RESULTS

3.1 SUMMARY OF PREVIOUS INVESTIGATIONS

The PIB SLERA relies heavily on the extensive documentation and efforts of PA DEP, its partners, and other researchers in evaluating the PIB AOC conditions. The dataset and ecological exposure assessments described below have been used to identify the existing lines of evidence that support an interpretation of the COPCs' effect on ecosystem receptors. Table 3.1 summarizes the previous investigations conducted within PIB and the primary components supporting the CSM processes. By linking PIB studies to the CSM, components can be identified that depict the known and unknown pathways to support a weight-of-evidence assessment of COPC impacts and trends relative to ecosystem receptors.

The focus of most of the investigations within PIB has been on the distribution and potential impact of COPCs in sediments. Earlier studies within PIB focused on legacy contaminants in sediments as the potential source of toxicity causing fish tumors (Obert 1993), as opposed to the overlying water column. For example, Obert (1993) sampled water quality above sediments within the Bay and found no clear correlation between elevated levels of sediment chemicals observed and water column chemicals. Diz (2002) describes the water quality in PIB to be satisfactory, and MacDonald (2008) describes legacy contaminants in PIB as the most important routes of COPC exposure. Thus, the bulk of the evaluations of toxicity in PIB have been focused on sediments (Table 3.1 and Attachment 2).

Whole sediment toxicity tests were conducted on PIB sediment samples in 2005 (Kemble et al. 2006) and are summarized in Attachment 1 and used as a line of evidence in the SLERA. Diz (2002) evaluated macroinvertebrate community structure within PIB, but no reference areas were evaluated as part of the study for comparison.

Attachment 1 provides summaries of each of the investigations identified in Table 3.1. The agency and stakeholder efforts examining the PIB AOC conditions are extensive, and the supporting investigations and rationale in the delisting of the dredging BUI in 2006 (PA DEP 2006) provide a comprehensive but not entirely updated source of information for the ERA. Supplemental analyses were conducted to expand and update existing PIB data sets using data gathered from PA Sea Grant and PA DEP (described later in this section).

Table 3.1. PIB AOC investigations evaluating sources, processes and ecological receptors potentially affected by COPCs.

Study (abbreviated title)/Data. (Expanded summaries provided in Attachment 2.)	Conceptual Site Model Components Described		
	COPC Source	Sediment Processes (Transport and Fate)	Receptors
PIB RAP (1992)	(PAHs primarily) Legacy (in-bay) sediments, SSOs and CSOs (primary), groundwater, nonpoint and atmospheric (secondary)	Suspended sediment inputs and deposition	Fish and Wildlife - No link to fish tumors confirmed, no indication of wildlife impairment
PIB RAP Update (2002)	Legacy (in-bay) sediments	Deposition	Bullheads
Diz (2002) Sediment Quality in PIB	ND	Deposition and burial	Macroinvertebrates, *Dreissena*, gastropods and amphipods
Diz (2005)	SSOs and Tributaries	Deposition and burial	ND
Kemble et al. (2006) PIB toxicity evaluation	Legacy (in-bay) sediments	Deposition	Amphipod and midge
Foyle and Norton (2006) Sediment Loading in PIB	Tributaries, Lake Erie	Erosion, resuspension, deposition (accretion), loading	ND
Gannon University (2007) Atmospheric PAHs in PIB	(PAHs only) Atmospheric	Deposition	ND
MacDonald (2008)	SSOs. CSOs and Tributaries	Deposition	Sediment dwelling organisms (all COPCs), benthic invertivors (Cd, Pb)
Rafferty et al. (2009) Historical review of BUI	PAHs only	Deposition	Bullheads
Blazer et al. (2009) Assessment of BUI on bullheads- Liver neoplasia	PAHs only	Deposition	Bullheads
Blazer et al. (2009) Assessment of BUI on bullheads- Orocutaneous tumors	PAHs only	Deposition	Bullheads
NOAA (2011) Musselwatch Data for Lake Erie (unpublished data)	PAHs and some metals	Deposition	Mussels

PA DEP and its USGS partners compiled a sediment chemistry database containing data from most of the sampling efforts conducted within PIB. The following describes the follow-up evaluations using the PA DEP and USGS data to build upon the evidence of COPCs' effects from sediments within PIB. The sample datasets were evaluated many different ways in an effort to understand and identify sample patterns and trends within and across the Bay. A geodatabase was developed to depict spatial patterns of samples because some samples within the dataset were poorly described by their spatial coordinates and appeared to be located outside the AOC. These samples were eliminated from further analysis. Other samples eliminated from analysis within the AOC analysis included samples located within areas dredged for navigation and mooring. Finally, samples collected by the USACE in the 1980s were deemed questionable for analysis because of a lack of QA/QC procedures for sampling and processing, as well as the poorly described sample locations (Diz, personal communication 2011).

Two primary sediment databases were combined (PA DEP and USGS), and one minor fish tissue dataset (PA DEP) was used to further evaluate sediment concentrations and exposure within PIB. The following describes the datasets, some of which included data from overlapping investigations.

> MacDonald (2008) compiled datasets of sediment chemistry from investigations focused on PIB. Studies dated from 1982, 1986, 1991, 1993, 1994 (two studies), and 2002 (two studies) data collections. Sediment quality conditions were evaluated from each study, and information on the chemical composition of whole sediments was compiled for both surficial and subsurface sediment samples. Samples were divided into three areas of interest: Presque Isle Bay AOC, Presque Isle ponds (outside AOC), and the near-shore areas of Lake Erie. Sediment samples included 212 surficial samples: 157 within the AOC described spatial descriptions of the samples (Diz, personnel communication 2011). The data were structured such that the evaluations were limited to the COPCs described by MacDonald (2008; Table 3.2 above), 38 within the ponds, and 17 near-shore in Lake Erie. Datasets were further evaluated by pre-AOC listing (1982-1991) and post-AOC listing (1992-2001) periods.
>
> PA DEP (2006) – Sediment samples were collected during 2003 and 2005 to support the evaluation of ecosystem health. In 2003, 11 historically sampled locations were resampled using a ponar grab sample within the PIB AOC boundary. In 2005, core samples were collected to attempt to assess temporal trends at four locations. The cores were cut into sections for analysis, and each section was mixed and analyzed. Analysis sections included surface samples at 0-5 cm, 5-10 cm, 10-30 cm, 30-50 cm, and 50-80 cm. Each section was dated using Pb210 and Cs135 isotopes. Additionally, to assess compliance with ecosystem health targets, surficial sediment samples were collected from 32 locations, with 12 samples collected from directed point sampling stations based on historical sampling locations and 20 samples from randomly selected locations. The top 4 inches of sediment was collected using a Van Veen grab sampler.
>
> Fish tissue data were provided by PA DEP. Although the tissue data was collected for the purpose of supporting the fish consumption advisory program (http://www.portal.state.pa.us/portal/server.pt/community/fish_consumption/), the data may offer some insight into the relative level of fish exposure to local

contaminants. The fish tissue dataset included samples collected between 1989 and 2003 within and near PIB. Eighteen species were represented, although a smaller set (N = 9) included species collected within and outside the Bay. The COPCs for PIB (metals and PAHs) are generally not bioaccumulative, so fish tissue data are not typically collected for these parameters and no data exist for PIB fish. However, PCB and mercury fish tissue data were included in the tissue analysis, so these data are assessed in the SLERA for relative exposure comparisons.

3.2 SLERA DATA SUMMARY AND ANALYSIS

The data from the historical investigations were compiled in a geodatabase as part of the SLERA to easily link samples to locations within PIB. Thematic layers of dredged areas and bathymetry were included. Samples located within the dredged layers were eliminated. The bathymetric data were available at 2-meter intervals. This layer was included to identify shallow, near-shore areas across the Bay, recognizing that the 2-meter interval depth exceeds the typical depth of contact for many wading birds and wildlife.

A total of 12 studies looking at sediment chemistry were conducted between 1990 and 2009 and are included in the SLERA database. The data from these studies had differing degrees of spatial coverage and spatial focus. Some studies attempted to sample the same locations or areas as previous studies, while others focused on areas of particular interest (high concentrations of COPCs) for that study. The spatial coverage of surface sampling locations is presented in Figure 3.1. Investigations included surficial sediment and core sediment sampling. For the purpose of this document, the sediment composited over a depth of 0-15 cm was considered surficial sediment. Core data were used, if the resolution of the intervals was deemed to be sufficient, to provide an estimate of sediment quality temporal changes given sedimentation rates in PIB. The spatial location of core data available for analysis is given in Figure 3.2; only the two 2005 core stations were used for analysis. A summary of sediment chemistry data used in this document is provided in Table 3.2.

Table 3.2. Studies included in the SLERA database for PIB.

Study Name	Sample Year	Analytes Present		
		Metals	PAHs	TOC
USFWS 1990	1990	X	X	X
Gannett Fleming, Inc. 1993	1992	X	X	X
PA DEP 1993	1993	X	X	
Battelle 1994a	1994	X	X	X
USACE 1997	1997	X	X	
ECDH 1998	1998	X	X	
USGS 1999	1999	X		
Diz 2002	2000	X	X	X
ECDH 2002	2002	X		X
PA DEP 2003	2003	X	X	X
PA DEP 2005	2005	X	X	X
PA DEP 2009	2009	X	X	X

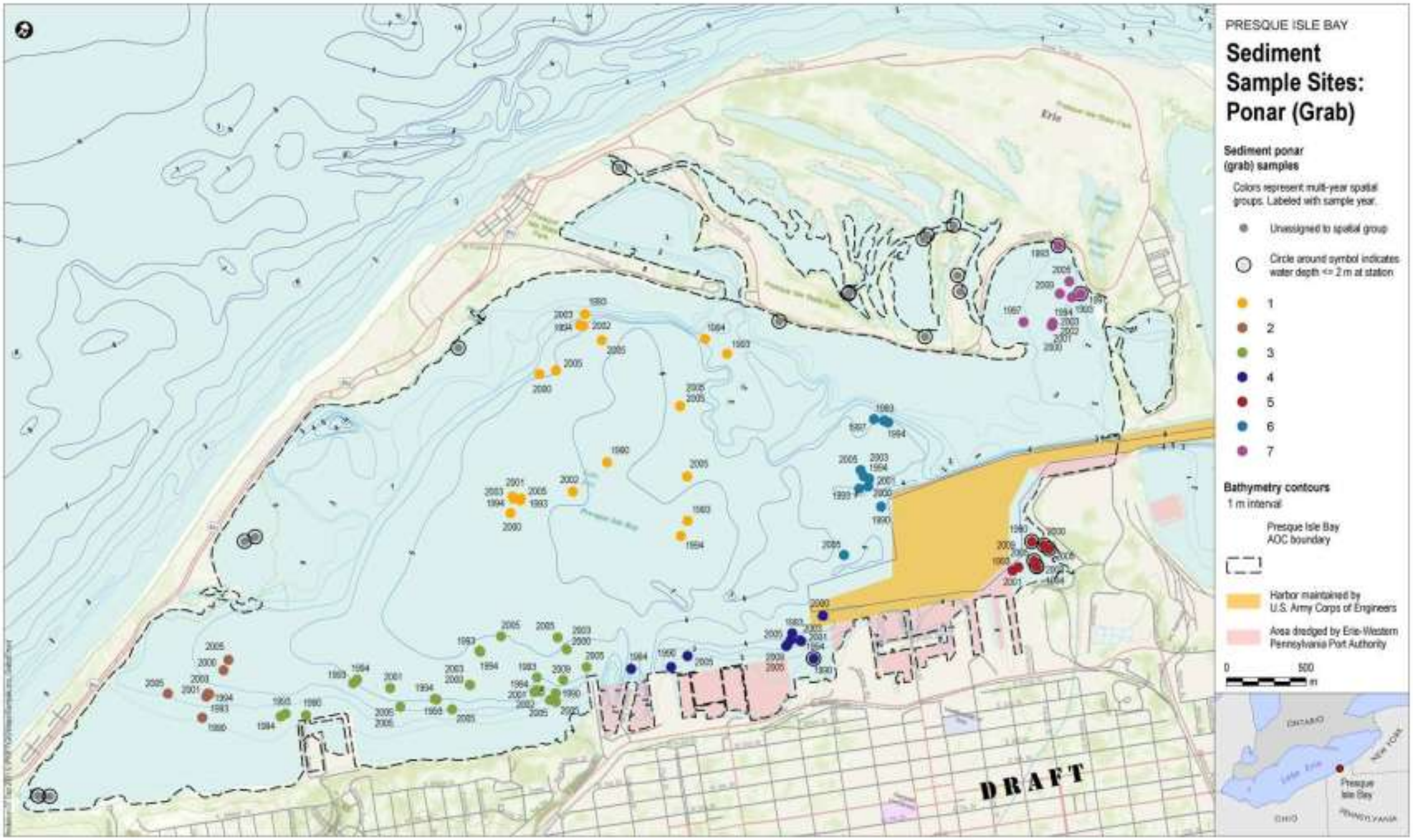

Figure 3.1. Surficial sediment sampling locations within PIB used in study.

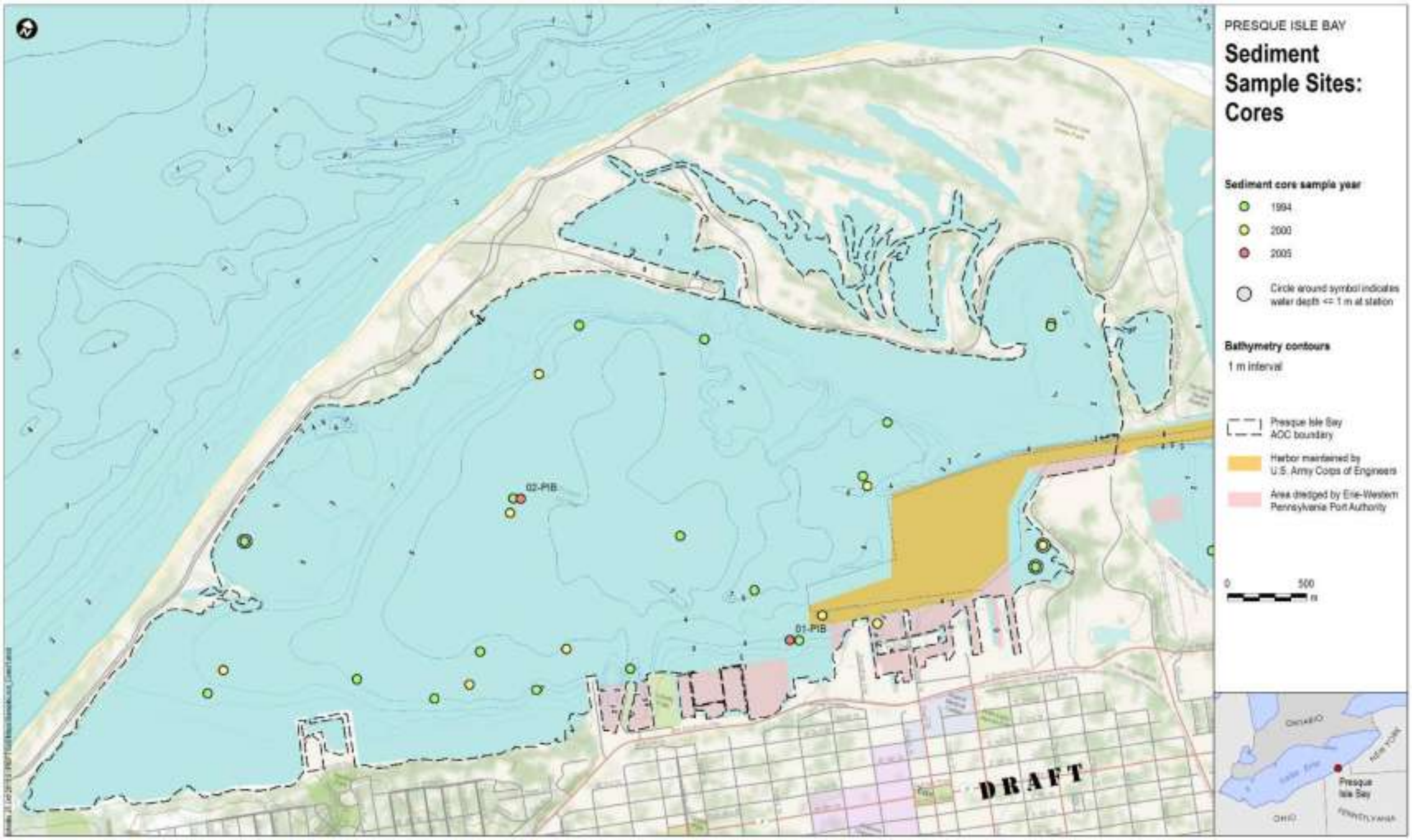

Figure 3.2 Core sediment sampling locations performed in PIB

Data for other exposure media such as the water column, sediment pore water, and food web components are not available. Water column data have been collected historically, but only the conclusions of the studies were reported. For example, Obert (1993) sampled water quality above sediments within the Bay and found no clear correlation between elevated levels of sediment chemicals observed and water column chemicals. Diz (2002) describes the water quality in PIB to be satisfactory. No data have been collected for sediment pore water or food web components. As such, the sediment data serve as the primary basis for the SLERA.

3.3 BENTHIC INVERTEBRATE RISK ASSESSMENT

A number of studies have assessed the sediment COPC data in comparison to freshwater sediment quality guidelines applicable to PIB. The sediment quality guidelines from these studies are presented in Table 3.3. Comparison of sediment COPC data to these guidelines comprise the exposure and effects assessment portion of the SLERA for the benthic invertebrates. These guidelines are not site-specific, are considered conservative, and do not indicate that an effect will be witnessed if the guideline is exceeded (Long et al. 1998). Much of the toxicity data used to develop such guidelines are based on whether effects were observed in bioassays from field-collected samples.

Table 3.3. PIB sediment quality guideline sources used in the ERA.

Description	Study	Magnitude of Effect and Criteria	
		Low	High
Bulk Sediment Quality Benchmarks (Average*PEC-Q)	MacDonald (2008)	<1 and <6 PEC exceedances per sample	>=1 or >=6 PEC exceedances per sample
	Diz (2005)	NA	NA
	PA DEP (2006)	<1 and <6 PEC exceedances per sample	>=1 or >= 6 PEC exceedances per sample
Metals Mixtures (SEM-AVS)	MacDonald (2008)	(SEM-AVS) < 0	(SEM-AVS) > 0
	Diz (2005)	(SEM/AVS) <1	(SEM/AVS) >1
	PA DEP (2006)	(SEM-AVS) < 0	(SEM-AVS) > 0
Metals Mixtures with Organic Carbon (SEM-AVS)/f_{OC}	MacDonald (2008)	<130	>130
	Diz (2005)	NA	NA
	PA DEP (2006)	<3000	>3000
PAH Mixtures (ESB-TU)	MacDonald (2008)	<1	>1
	Diz (2005)	NA	NA
	PA DEP (2006)	<1	>1
*Median is used to reflect central tendency of COPCs			

For this SLERA, the median PEC-Q was the parameter used for analysis of bulk sediment quality. The PEC-Q is the ratio of the concentration of the contaminant to its PEC value. For each sample location, the median PEC-Q was chosen because the data are log-normally distributed and contained many outliers that would bias the arithmetic mean PEC-Q value. The median is a better representation of central tendency (average) of the data and average exposure, so this criterion was used for this assessment (Table 3.3).

3.3.1 Sediment COPC Data

Surficial and core sediments were evaluated for sediment quality in PIB. Most of the studies performed in PIB focused on surface sediment, but the sediment cores collected in 2005 were evaluated to attempt to observe a trend of the chemical concentrations over time.

3.3.1.a Core sediments

Sediment cores were collected in 1994, 2000, and 2005 from the locations depicted in Figure 3.2. Of these, only the two of sediment cores collected and analyzed in 2005 by PA DEP were vertically segmented at relatively fine depth intervals, sub-sampled and analyzed for COPCs. The 1994 and 2000 cores were subsampled at relatively coarse vertical intervals so vertical profiles are not discernible from the data. Plots of the concentrations of COPCs in the two 2005 sediment cores are shown in Figures 3.3 to 3.6. Figure 3.3 and 3.4 show the results of metals and PAHs, respectively from the finely segmented core collected in the near shore location in PIB and Figures 3.5 and 3.6 show the results for the central Bay core. Lines depicting the PECs and TECs are shown on the plots for comparative purposes. Generally, the concentrations of metals in both cores were at a maximum in the 10-30 cm core interval, and have shown a decreasing trend in the surface (< 10 cm) sediments. These profiles suggest that loadings of metals to the Bay peaked years ago and have since declined, and the historically deposited sediment has been buried by more recently deposited sediment with lower metals concentrations. Concentrations of arsenic, cadmium and lead in the surface samples from both cores have declined and are below PECs. Concentrations of nickel and zinc have declined over time as well, but exceed PECs at these two locations. The concentration of PAHs in the near-shore core (Figure 3.4) has a peak in the shallow sediments, indicating a more recent source and/or resuspension and redeposition of surface sediments. The PAH concentrations in the central Bay core (02-PIB) show a slight decrease in shallow sediment concentrations from the maximum sediment concentrations at deeper intervals, consistent with the profile of metals and suggest. Concentrations of PAHs are higher in the near-shore core than at the central Bay location. PECs for PAH constituents are exceeded in the surface sediment at both locations, but the total PAH concentrations are below the total PAH PEC.

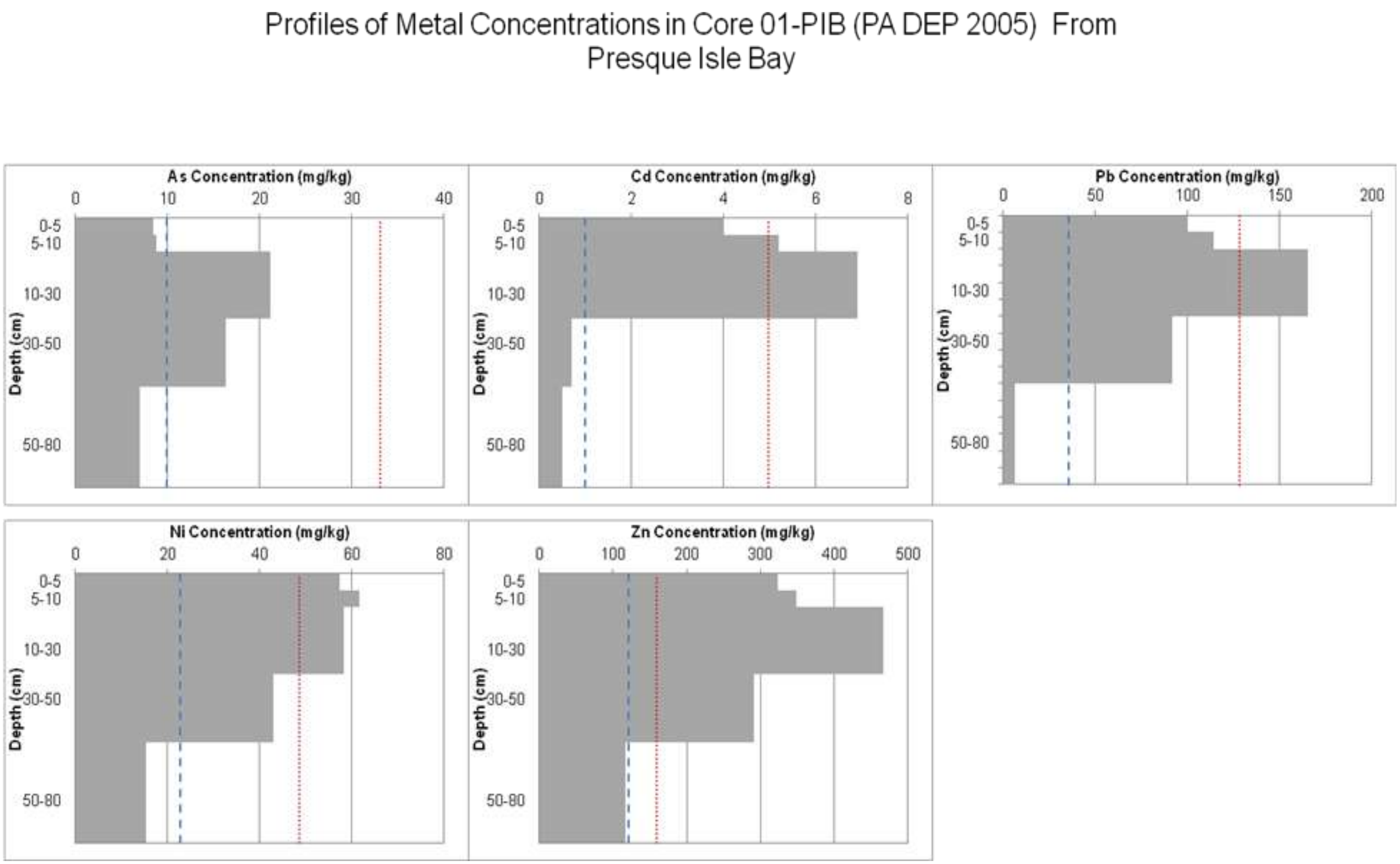

Figure 3.3 Sediment core profiles for metals in 2005 near-shore sampling location.

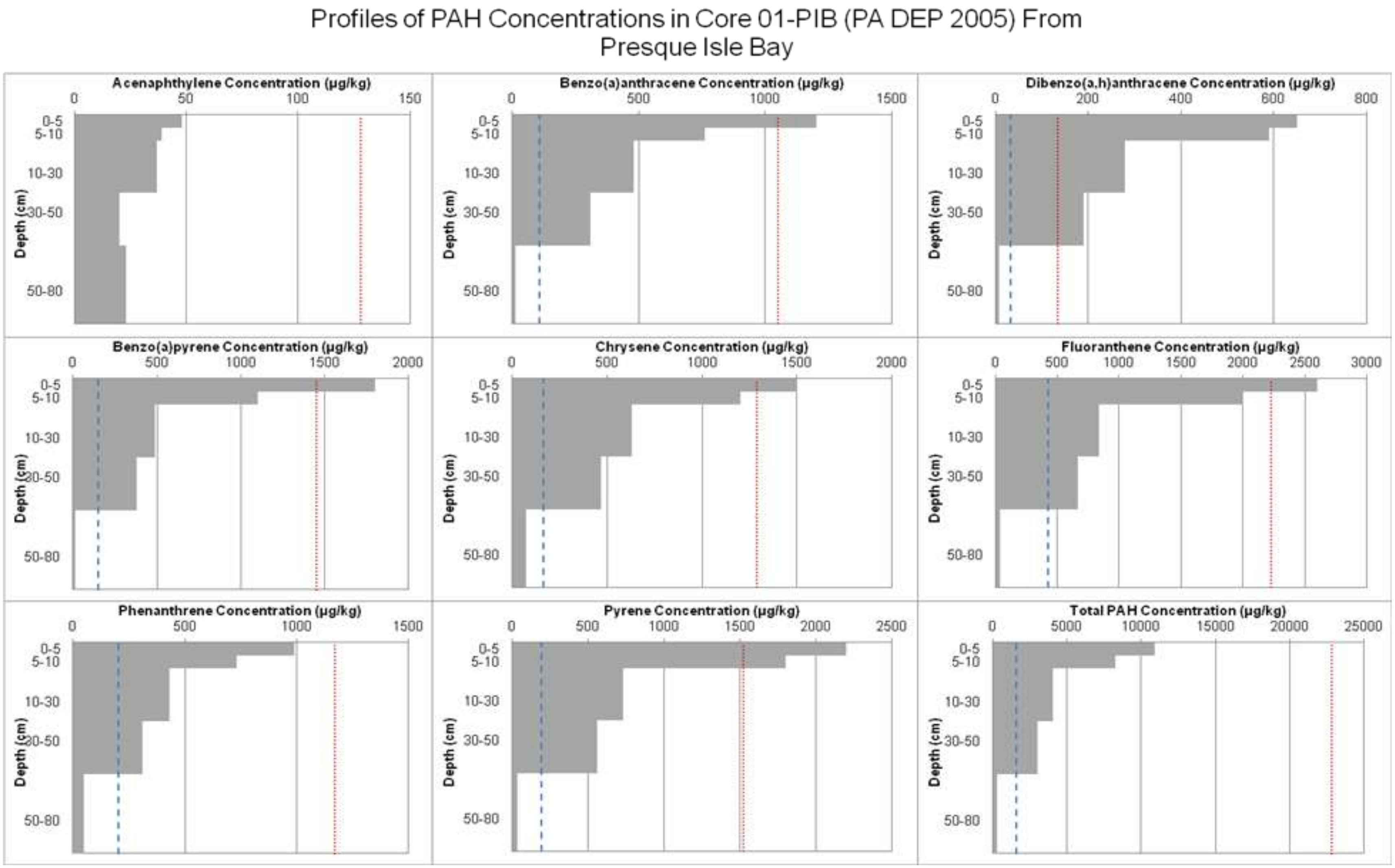

Figure 3.4. Sediment core profiles for PAHs in 2005 in the near shore sampling location.

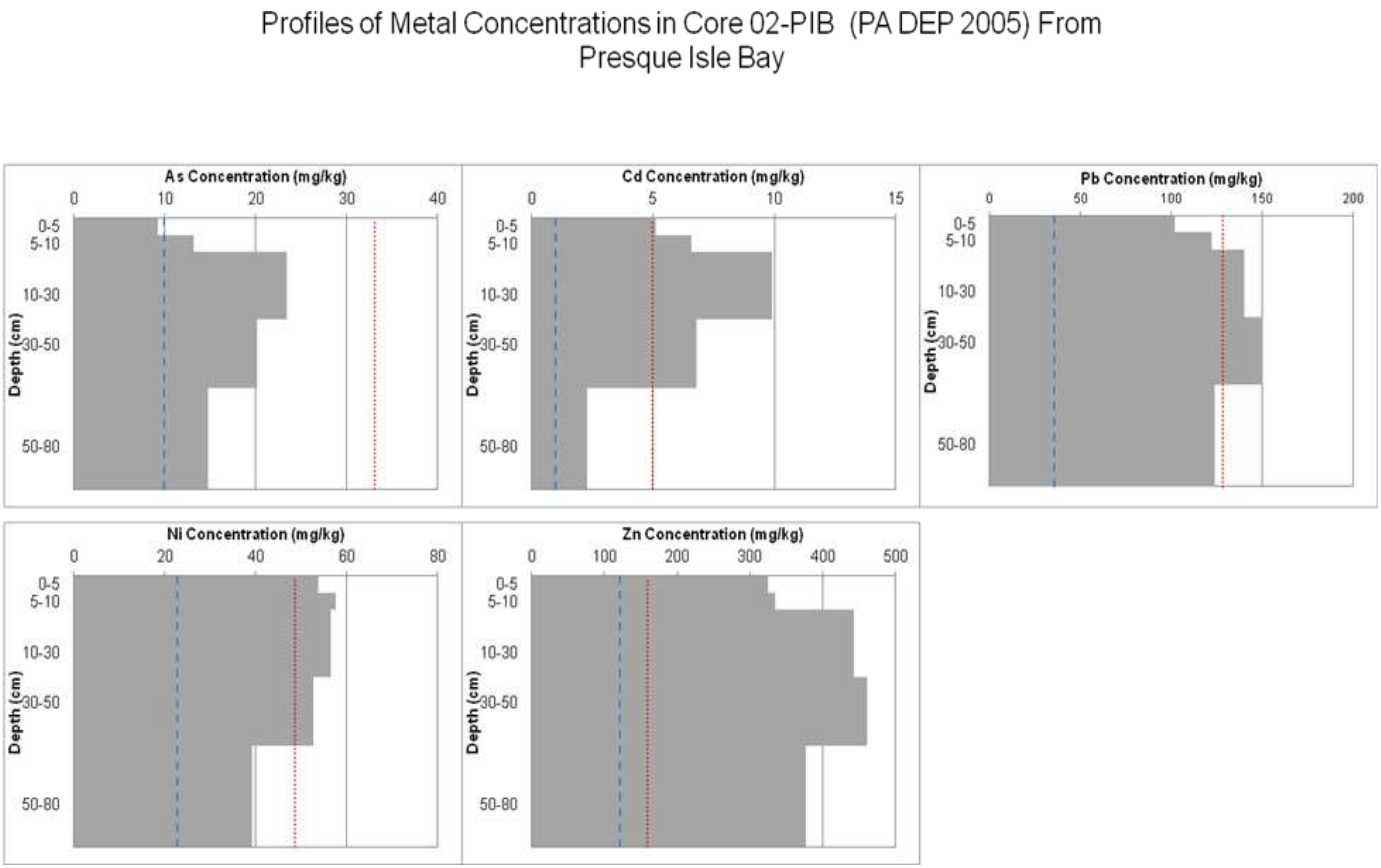

Figure 3.5. Sediment core profiles for metals in 2005 from the central Bay sampling location.

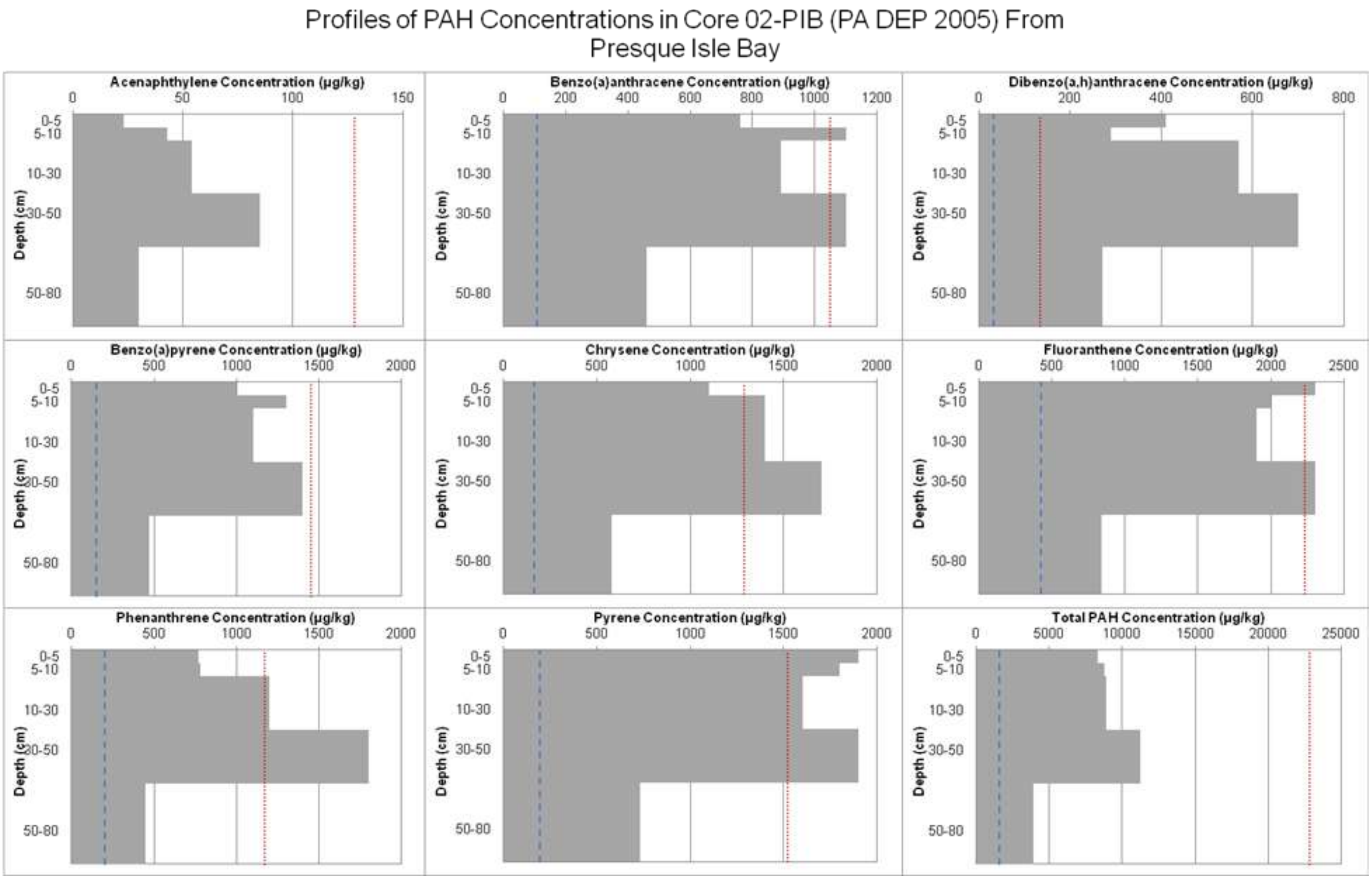

Figure 3.6. Sediment core profiles for PAHs in 2005 central Bay sampling location.

3.3.1.b Surface Sediments

The data available for surface sediment were temporally and spatially varied in PIB. Sampling locations of the surface sediment samples are shown above in Figure 3.1. The COPC concentrations were evaluated in comparison with the metrics presented in Table 3.3, as discussed below for each metric.

PEC-Q

The distribution of concentrations of COPCs in surface sediments are plotted in Figures 3.7 and 3.8, for metals and PAHs, respectively. The “box and whiskers” plots show the range and quartiles of the data for each COPC analyzed as well as the TECs and PECs for each COPC. As is evident in Figure 3.7, with the exception of barium, the majority of metals concentrations in the surface samples collected since 2000 are below PECs. Similarly, the plots presented in Figure 3.8 show that PAH concentrations in the majority of surface sediment samples collected since 2000 are below PECs. Median PEC-Qs were calculated for surface sediment samples collected over time from seven spatial zones (stations) and the combined near-shore areas of PIB shown in Figure 3.1. The median PEC-Q represents the average PEC-Q of all COPCs in a given sample. The results of the spatial and temporal analysis are shown in Figure 3.9. As evident from Figure 3.9, the vast majority of median PEC-Qs were less than 1 for all individual spatial areas and sampling years. No discernible temporal trend was observed, likely reflecting the high variability in surface sediment concentrations and varying sampling objectives and methods from year to year.

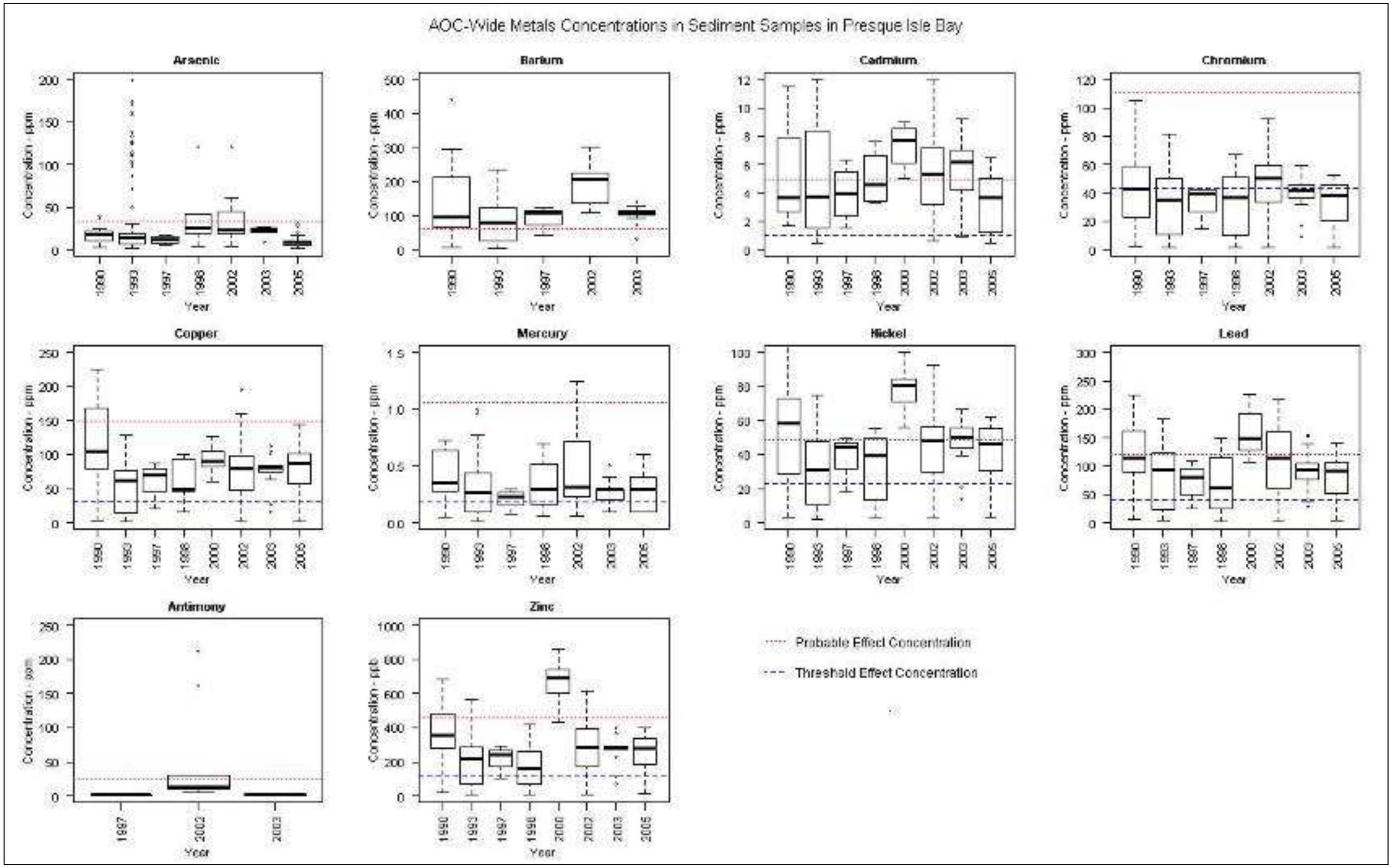

Figure 3.7. Metals concentrations of Bay-wide sediments in PIB.

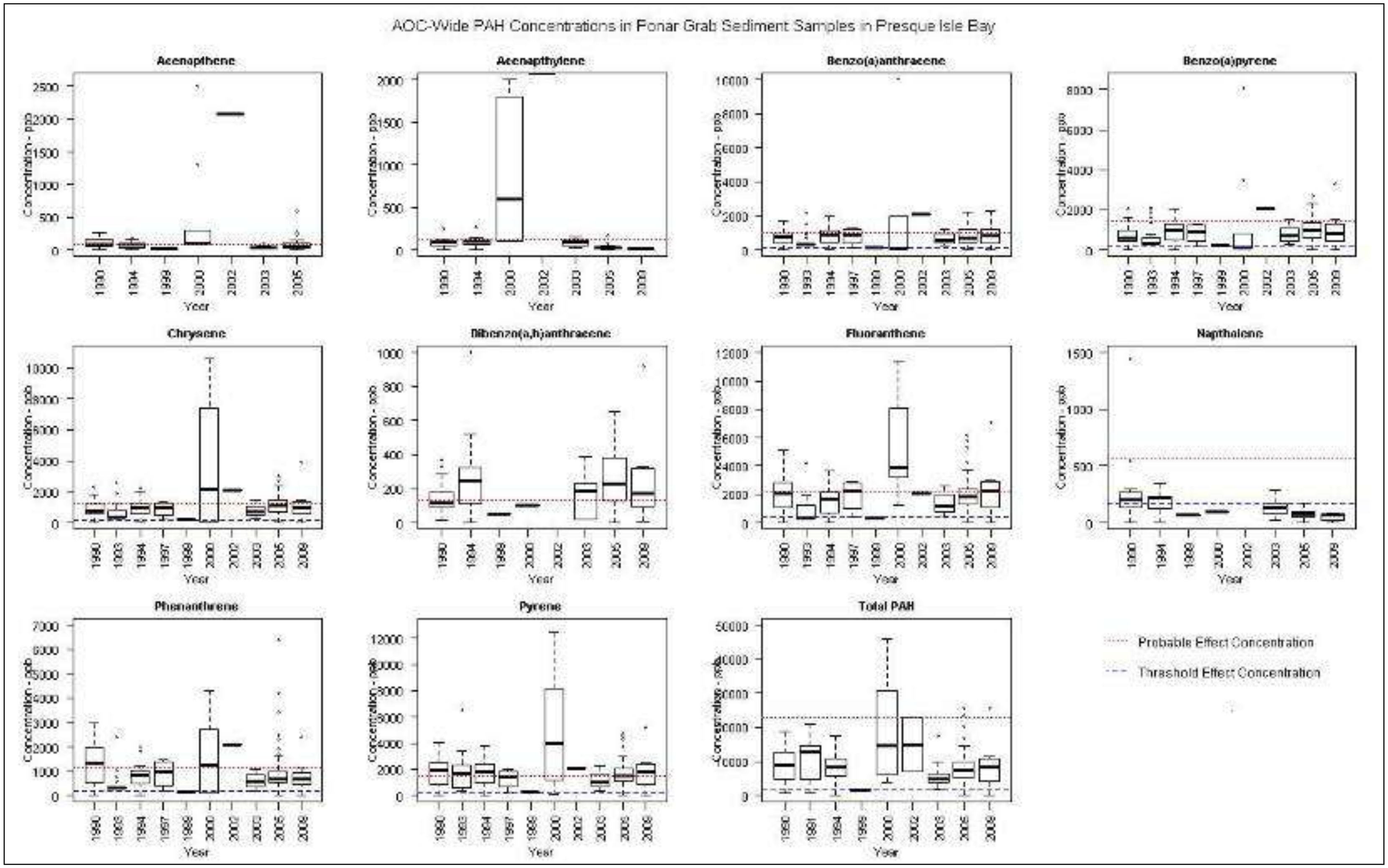

Figure 3.8. PAH concentrations of Bay-wide sediments in PIB.

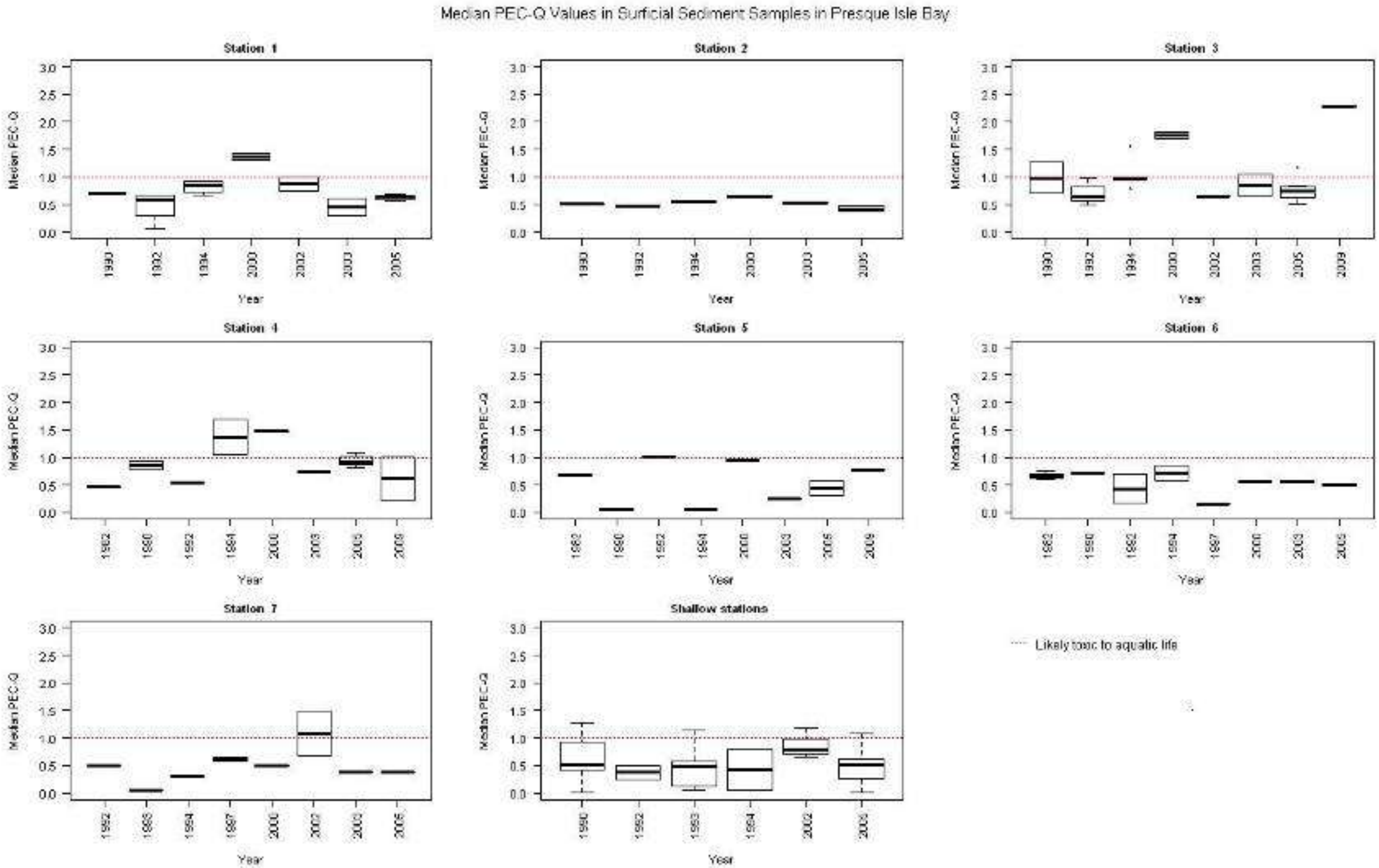

Figure 3.9. Median PEC-Q values for surface sediments in PIB, by station number represented in Figure 3.1, and shallow areas (< 2m).

Table 3.4 shows that the median PEC-Q values across all sampling locations were below the threshold of 1.0, except for the samples collected in 2000. The majority of samples (57%- 100%) had median PEC-Qs that were less than one and the majority of samples had fewer than six PEC exceedances, except for samples collected in 2000. However, the target to achieve median PEC-Qs and fewer than six PEC exceedances for at least 90% of the sampling was not consistently met and was not met in the most recent sampling events. The results for sampling conducted in 2000 were significantly different than results for other years most likely because the 2000 investigation targeted "…sediments from locations identified in previous studies as having high concentrations of contaminants, or having exhibited toxicity in previous testing" (Diz 2002). The focus on potentially highly contaminated sites in 2000 study helps to explain why the samples collected in 2000 had higher concentrations than samples collected from random locations in other years.

Table 3.4. Studies meeting criteria for bulk sediment quality targets

Sample Year	Percent of stations meeting Median PEC-Q criteria	Median PEC-Q Value for All Samples	Stations with >=6 PEC Exceedances	Sample Count	Dataset
1990	55%	0.71	5	11	USFWS 1990
1992	72%	0.54	5	18	Gannett Fleming, Inc. 1993
1993	68%	0.48	0	88	PA DEP 1993
1997	100%	0.58	0	3	USACE 1997
1998	100%	0.23	0	2	ECDH 1998
2000	0%	1.31	7	9	Diz 2002
2002	50%	0.76	2	10	ECDH 2002
2003	78%	0.56	2	9	PA DEP 2003
2005	66%	0.59	10	29	PA DEP 2005
2009	67%	0.60	1	6	PA DEP 2009

(SEM-AVS) and (SEM-AVS)/f_{oc}

To analyze the potential toxicity of metals, the values of (SEM-AVS) and (SEM-AVS)/f_{oc} were calculated for the two studies, Diz (2002) and PA DEP (2005), where AVS data were available. The methods from the Ohio EPA (2010) were used to calculate (SEM-AVS) and (SEM-AVS)/f_{oc} at each station. The target criteria of (SEM-AVS) < 0 from PA DEP (2006) and (SEM-AVS)f_{oc}< 130 from Ohio EPA

(2010) were used. The percentage of samples meeting these criteria can be seen in Table 3.5; the spatial distributions and results of the samples are given in Figure 3.10 for (SEM-AVS) and Figure 3.11 for (SEM-AVS)/f_{oc}.The table and figure show that, generally, the samples meet the target of 90% of samples meeting their respective criteria, even when the targeted high concentration sediments are included. This indicates that the metals concentrations in PIB are meeting acceptable levels.

Table 3.5. Results of analysis for (SEM-AVS) and (SEM-AVS)/f_{OC}

Sample Year	Sample Count	Samples Meeting Criteria (SEM-AVS)	Samples Meeting Criteria (SEM-AVS)/fOC	Dataset
2000	9	67%	100%	Diz 2002
2005	27	93%	93%	PA DEP 2005

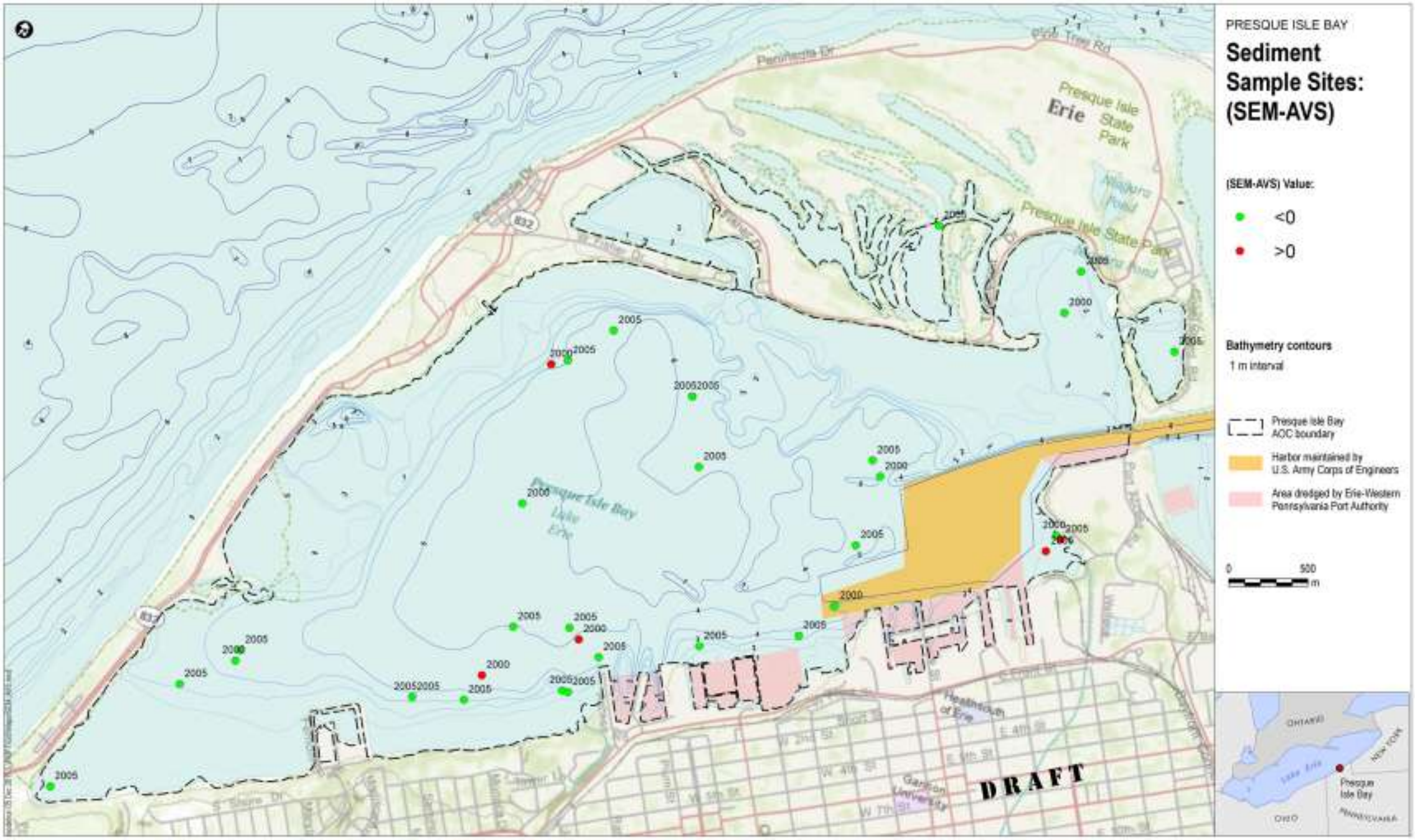

Figure 3.10. Sampling Locations and Results for (SEM-AVS) Analyses in PIB Surface Samples.

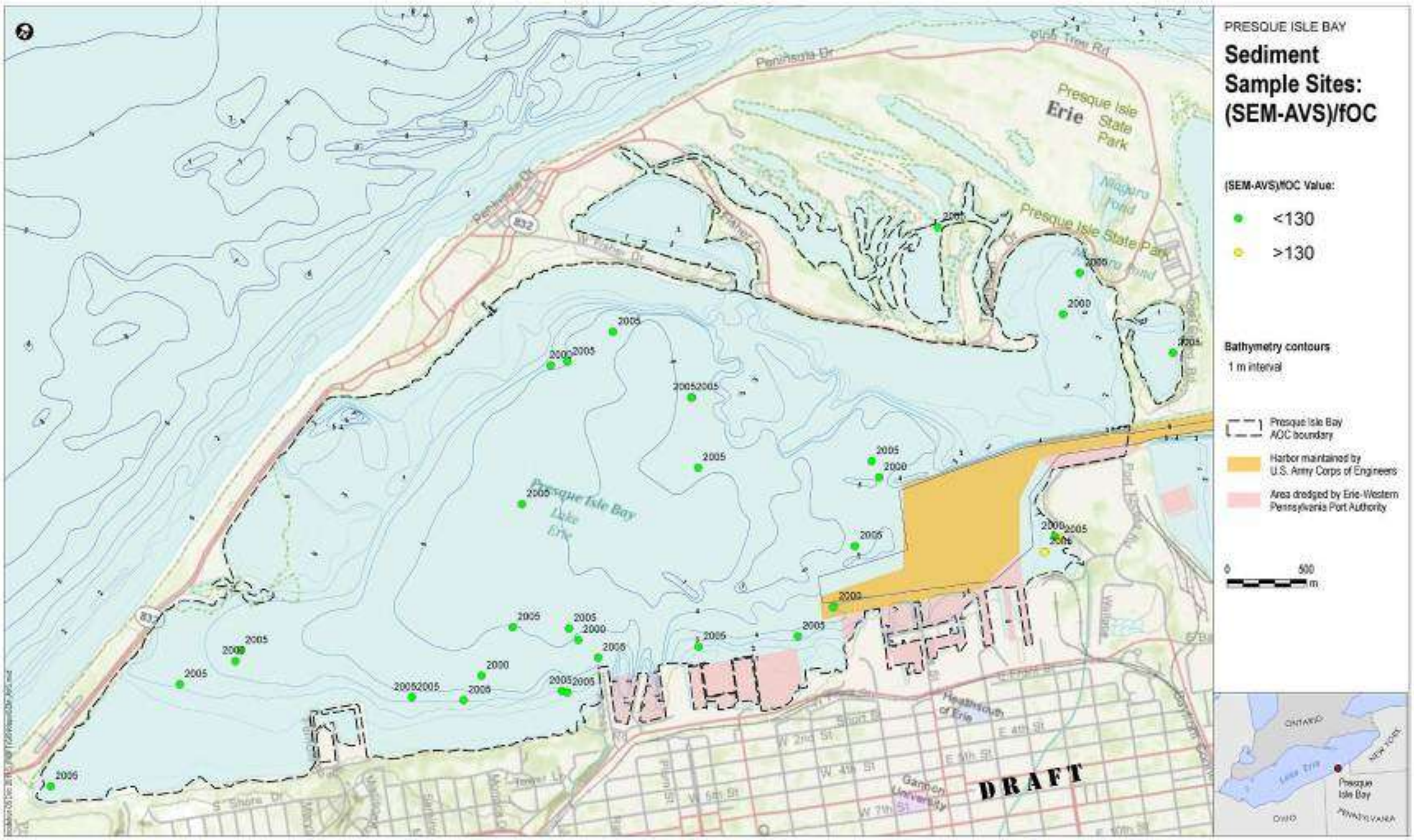

Figure 3.11. Sampling Locations and Results for (SEM-AVS)/f_{OC} Analyses of Surface Samples in PIB.

ESB-TU

As an additional line of evidence to characterize the toxicity of total PAHs and attempt to for sample specific bioavailability, ESB-TUs were calculated for datasets where PAH and sediment TOC data were available. The methods from the Ohio EPA (2010) were used to calculate ESB-TUs at each station. The target criteria of ESB-TUs less than 1.0 from PA DEP (2006) were used. The results of the analysis are shown in Table 3.6 and depicted in Figure 3.12, and indicate that the criteria are essentially met for all sample years with the exception of samples collected in 2000.

Table 3.6. Results of ESB-TU Analysis

Sample Year	Sample Count	Samples Meeting Criteria	Dataset
1990	11	100%	USFWS 1990
1992	18	89%	Gannet Fleming, Inc. 1993
1994	19	95%	Battelle 1994a
2000	9	67%	Diz 2002
2003	9	100%	PA DEP 2003
2005	36	94%	PA DEP 2005
2009	5	80%	PA DEP 2009

However, there is uncertainty in the ESB-TU calculations because only a subset of PAH constituents were typically analyzed for the PIB sediments. The ESB-TU calculation method is based on the analysis of 34 PAHs, and analytical data for only 13 PAHs were consistently available for PIB samples. To characterize the uncertainty, the method specifies uncertainty factors to be applied for different levels of confidence when analysis data for < 34 PAHs are available. However, these uncertainty factors should be locally derived because of the unique distribution of PAHs in contaminant data resulting from their source(s) (Burgess 2009). Establishing locally appropriate levels of uncertainty were outside the scope of this SLERA. Rather, Table 3.7 and Figure 3.13 show the results of the ESB-TU analysis at a 90% confidence level using previously developed, Ohio EPA (2010) data. While the ESB-TU criteria are met for the majority of surface samples without the inclusion of uncertainty factors, they are not met for the majority of samples if the uncertainty factors are included, and therefore attainment of these criteria in PIB is inconclusive.

Table 3.7. ESB-TU Analysis with Inclusion of Uncertainty Factor for 90% Level of Confidence

Sample Year	Sample Count	Samples Meeting Criteria
1990	11	45%
1992	18	22%
1994	19	47%
2000	9	56%
2003	9	26%
2005	36	11%
2009	5	0%

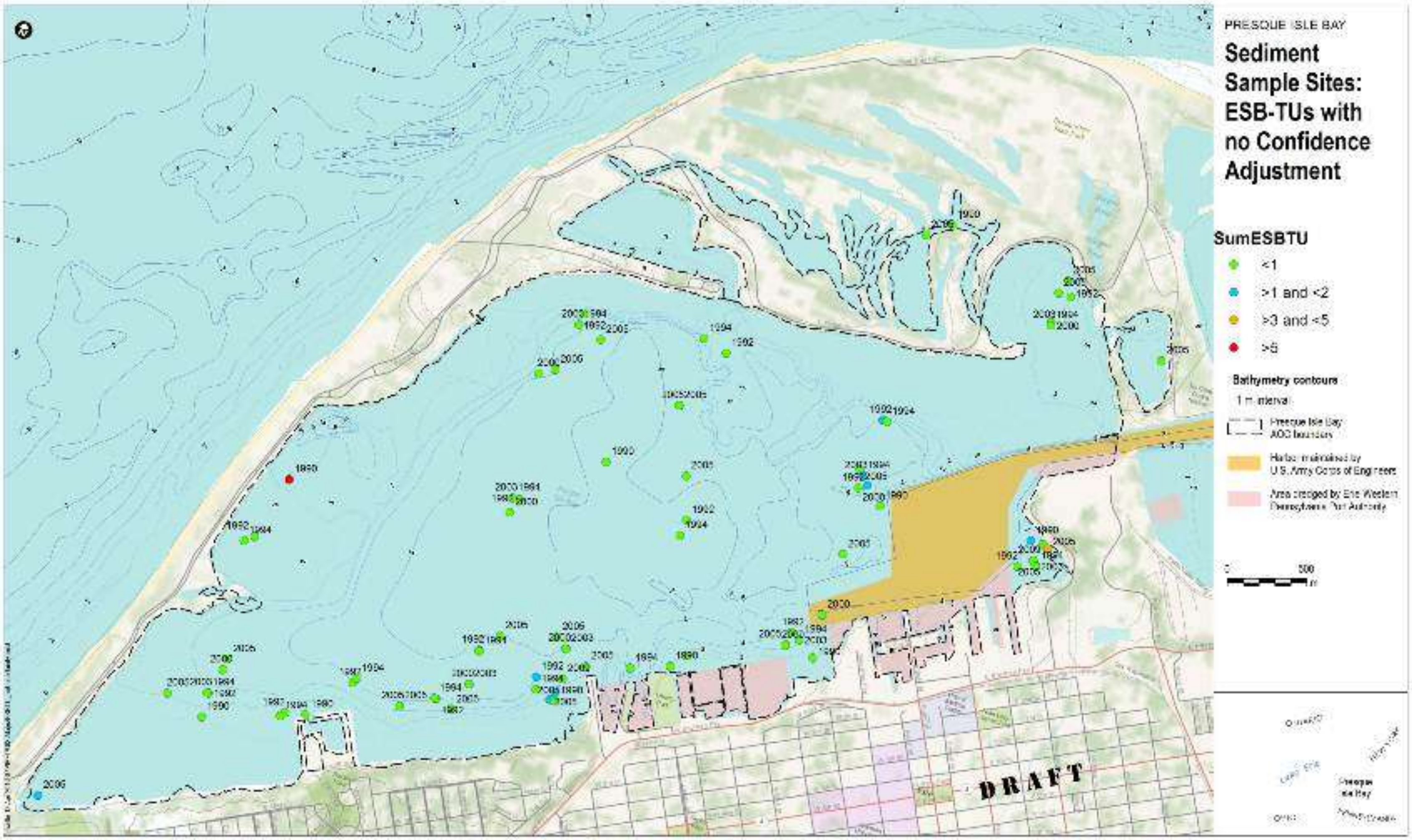

Figure 3.12. Location and Results for ESB-TU Analyses for PIB Sediment

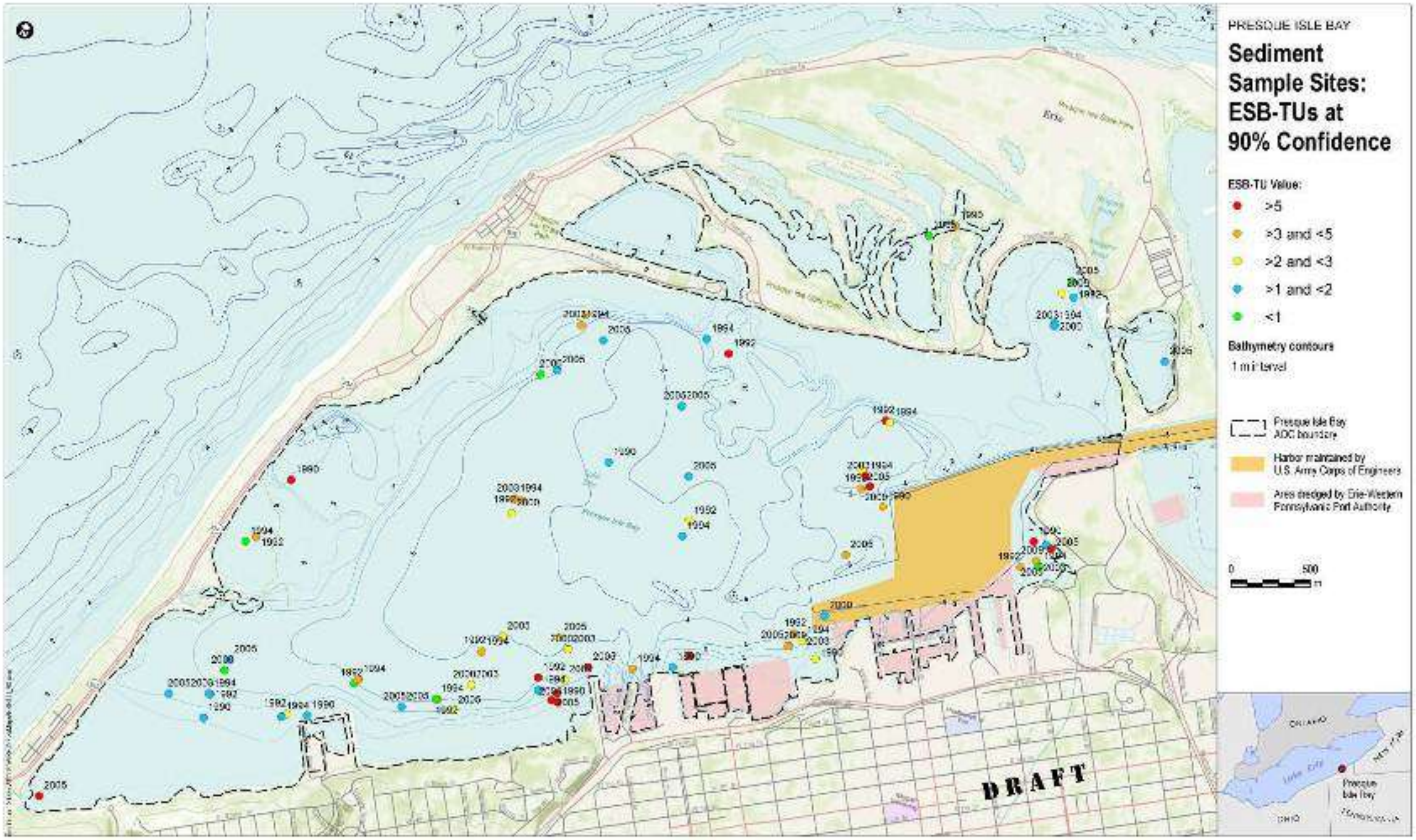

Figure 3.13 – Sample Locations and Results for ESB-TU Analyses with Inclusion of Uncertainty Factors

3.3.2 Whole Sediment Toxicity Test Results

Whole-sediment toxicity was evaluated using the results of 10-d toxicity tests with the midge, *Chironomus dilutus*, and 10- and 28-d toxicity tests with the amphipod, *Hyalella azteca* (Endpoints: survival or growth for both tests) at 21 stations in 2005 (Kemble et al. 2006). The results of the study are presented in Table 3.8.

Table 3.8. Summary of MacDonald (2008) findings of risk of exposure to benthic invertebrates by COPCs within PIB.

Year	Number of Samples	Potential Risk (Percent (n) of samples by risk category) Whole Sediment Toxicity		
		Low	Moderate	High
2005	21	67% (14)	5% (1)	29% (6)

Whole sediment toxicity risks were low at the majority (67%) of sampling locations throughout PIB and that evaluated samples posing a high risk (6 of 21) were located in shallow portions of the Bay (n= 5) and at the confluence of Mill Creek (n=1). MacDonald (2008) reviewed the whole-sediment toxicity tests along with whole-sediment COPC data compared with TRVs and concluded that overall, the potential risks to benthic invertebrates associated with exposure to COPC contaminated sediments were frequently low across PIB. Therefore, potential risks to benthic invertebrates are considered to be low, however isolated locations within PIB may pose a moderate risk to benthic invertebrates

3.3.3 Summary of Risk Characterization for Benthic Invertebrates

The results of the comparisons of PIB sediment data to the various target metrics discussed above is summarized in Figure 3.14. As is apparent from the plots, the majority of sediment COPC data meet the criteria for the various metrics. While all the targets for benthic invertebrates have not been consistently met for 90% of the historical surface sediment samples, all targets have been consistently met for the majority of samples collected over the past decade and the risks to benthic invertebrates from COPCs are low in most areas. As a result of the source controls that have been implemented historically, conditions are expected to continue to improve.

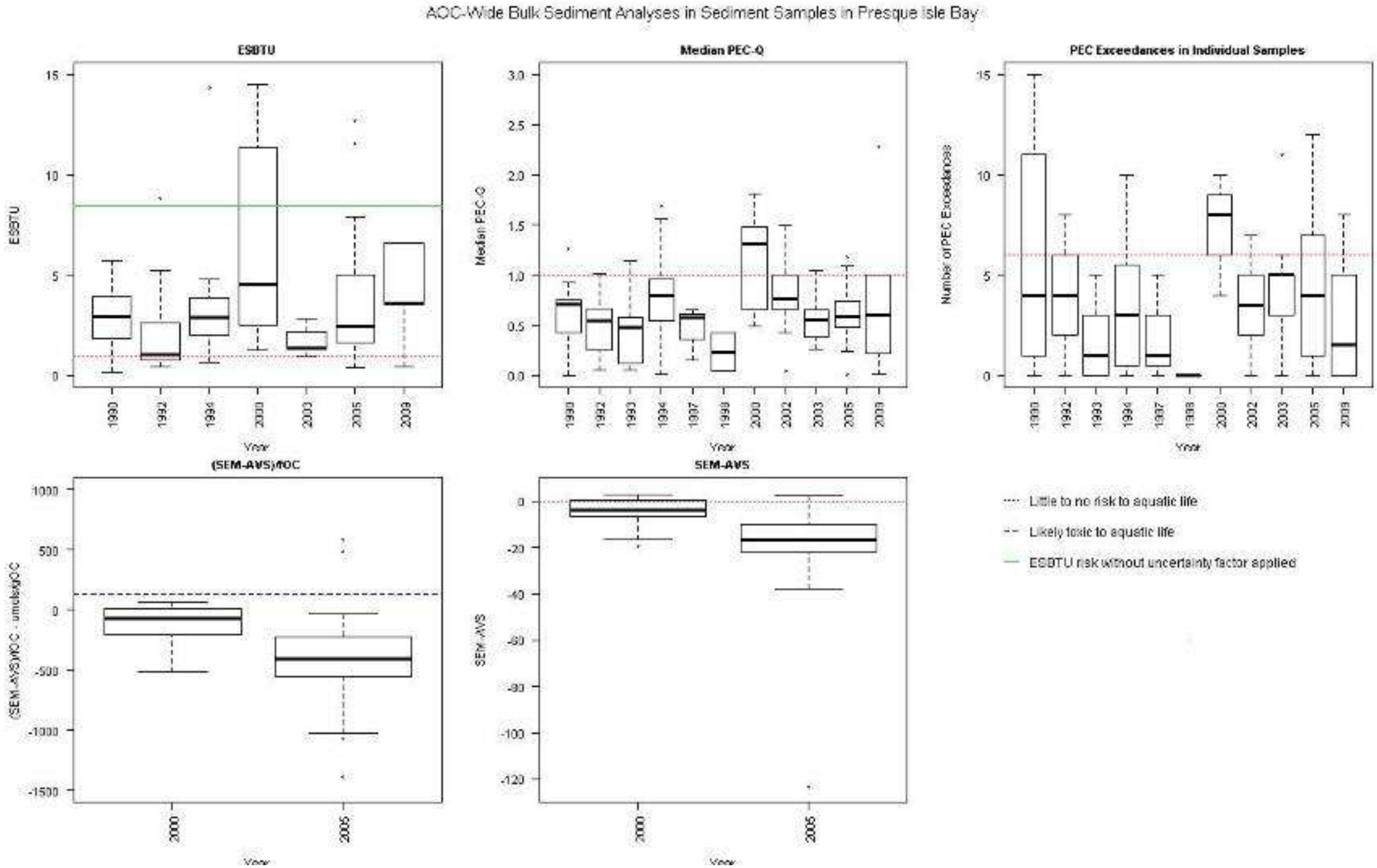

Figure 3.14. Bulk sediment analysis of Bay-wide PIB sediments

3.4 FISHERY RISK ASSESSMENT

Four lines of evidence were evaluated to assess the risks potentially posed by sediment COPCs to the survival, growth and reproduction of fish in PIB, consistent with the ecosystem objectives and targets discussed in Section 2.3.3b., including 1) water quality; 2) benthic fauna health; 3) fish tissue concentrations of COPCs; and 4) prevalence of lesions and tumors. The evaluation of each of these lines of evidence is presented below.

Water Quality

The first line of evidence to assess potential risks to fish in PIB would be an evaluation of the water quality in PIB to determine whether the concentrations of COPCs in water meet water quality criteria that are protective of aquatic species. No quantitative water quality data for the Bay were available for the SLERA, but historical investigation where water samples were reportedly collected and analyzed for PIB, concluded that the quality of the water column in PIB was good and that there was no correlation between sediment COPC concentrations and the overlying water column (PA DEP 1992).

Benthic Fauna

The second target for the protection of the survival, growth and reproduction of fish is to maintain conditions to support healthy benthic invertebrate communities to support fish communities. This is the same metric as was evaluated in the benthic invertebrate risk assessment as described above in the benthic invertebrate risk assessment. As discussed above, while there are localized areas where COPC concentrations in sediment may adversely impact the abundance and diversity of benthic invertebrates, risks from COPCs in sediments are low in most areas. Available information on TRVs for fish in PIB was insufficient to quantitatively evaluate fish exposure and resulting risks to fish posed by COPCs in benthic fauna that serve as a food source.

COPCs in Fish Tissue

Tissue sample, concentration data for fish were evaluated from fish consumption advisory data provided by PA DEP (http://www.portal.state.pa.us/portal/server.pt/community/fish_consumption/). There are no data for concentrations of COPCs in fish tissue, largely because most of the COPCs are not bio-accumulative and are typically not analyzed in fish tissue samples. Only PCB and Mercury were available for comparison. While these compounds (PCB and Mercury) were not identified as COPCs in historical PIB investigations, they are the primary bioaccumulative chemicals of concern for most of the Great Lakes AOCs, as well as contaminated sediment sites throughout the nation. PCB and Mercury are often the compounds of greatest concern to fish, wildlife and human health at contaminated sediment sites. As such, the evaluation of risks from PCB and Mercury in PIB provides a useful surrogate for assessing contaminant risk (or lack thereof) to fish and wildlife in PIB and serves as an indicator of relative risks to other contaminated sediment sites.

While only a handful of sample results for PCB concentrations in fish tissue collected from PIB were between 1998 and 2004 were available for the SLERA, the average PCB concentrations for the available five samples is 0.075 mg/kg with a maximum concentration of 0.28 mg/kg detected in a carp sample collected in 2000. These PCB concentrations are very low relative to fish tissue results for other areas of the Great Lakes and particularly for Lake Erie which are approximately an order of magnitude higher. In contrast to the sparse PCB data, much more data for Mercury concentrations in fish tissue collected from PIB were available. Mercury data for seven fish species were available for comparison of PIB levels with Lake Erie levels and are summarized in Table 3.9. The sample results indicate that there are no significant departures between the concentrations of Mercury measured in PIB fish and Lake Erie fish (Table 3.9) and that the concentrations of Mercury are relatively low.

Table 3.9. Fish tissue samples evaluated for Mercury from PIB and Lake Erie collections.

Range of Sample Dates		No. of Fish	Species	Location	Avg. HG	Max. HG	Min. Hg
11/14/2001	11/14/2001	1	Brown Trout	Lake Erie	0.07	0.07	0.07
9/11/1996	9/11/1996	1		PIB	0.17	0.17	0.17
10/17/1990	9/28/1999	4	Carp	Lake Erie	0.11	0.13	0.07
6/5/1995	8/10/2000	2		PIB	0.09	0.14	0.05
8/6/1996	8/13/2003	4	Freshwater Drum	Lake Erie	0.14	0.28	0.04
6/20/1995	6/20/1995	1		PIB	0.19	0.19	0.19
10/15/1993	10/13/2004	8	Smallmouth Bass	Lake Erie	0.19	0.29	0.08
6/5/1995	6/5/1995	1		PIB	0.14	0.14	0.14
10/24/1989	9/17/2002	7	Walleye	Lake Erie	0.27	0.44	0.07
6/20/1995	6/20/1995	1		PIB	0.15	0.15	0.15
8/20/2003	8/20/2003	1	White Perch	Lake Erie	0.09	0.09	0.09
6/20/1995	6/20/1995	1		PIB	0.16	0.16	0.16
8/1/1989	2/14/2010	16	Yellow Perch	Lake Erie	0.08	0.14	0.02
10/17/1990	10/25/1996	4		PIB	0.06	0.11	0.03

Fish Tumor and Lesion Prevalence and Population Level Effects

Although several studies have aimed to link causal effects of sediment PAH exposure to lesion prevalence, few have attempted to link lesion and tumor prevalence to adverse effects at the population or higher trophic level. Brown bullhead studies conducted on the Black River in Ohio reported liver histopathology data that suggested a link between sediment PAH concentrations, liver lesions, and population age structure (Baumann 2000). For example, Baumann (2000) noted a truncated age structure in the Black River population examined during the contaminated study period, whereby few individuals in the population survived beyond 4 years of age. Following site remediation (e.g., PAH removal), the cancer prevalence decreased along with the associated reference populations absent of PAH contamination.

In a study of English sole, Johnson and Landahl (1994) examined the relationship between lesion prevalence and population-level effects by comparing estimated annual mortality rates at both highly contaminated (e.g., Eagle Harbor) and uncontaminated sites throughout Puget Sound. English sole mortality rates from contaminated sites associated with high liver lesion prevalence were not found to be significantly greater than mortality rates for English sole from Puget Sound as a whole. The investigators also examined the population structure and found no evidence of increased age-related mortality in fish with lesions or in populations associated with areas of high concentrations of PAHs and PCBs. The authors concluded that fish populations that have high incidence of lesions do not necessarily have increased mortality. Other factors that affect English sole populations, such as fishing pressure, predation, and fluctuations in food supply, may mask population-level effects associated with chemical contamination and lesion incidence. Thus, Johnson and Landahl (1994) did not identify a link between lesion prevalence and population structure in areas with widely varying ranges of PAH concentrations in sediment, so the relationship remains uncertain.

Alternatively, a recent study by Breckles and Neff (2010) suggested that the historically contaminated (including PAHs) sites in the Detroit River have resulted in populations (such as bullhead) and an ecosystem that has adapted to and is tolerant of the legacy contaminant conditions, suggesting an evolved ecosystem response. Breckles and Neff (2010) also noted that more focused assessments at the community level are warranted, but their observations are worth noting nonetheless.

While these describe tumor incidences of benthic fish exposed to PAH-contaminated sediment, they are not conclusive with respect to population or higher-level effects due to this exposure. The incidence of abnormalities in fish remains a challenge to attribute to a single factor and is likely to result from confounding factors, including species, age, disease, organic matter, temperature, nutrition, season, and geographic location in addition to contaminants and catch methods (Adams et al. 1996). Because of the highly qualitative nature of the field health observations and the uncertainties associated with their interpretation, a conclusive link between the field observations of tumor prevalence and the affect on the population and community levels is lacking.

3.5 WILDLIFE RISK ASSESSMENT

For the wildlife risk assessment, three lines of evidence were evaluated to assess the potential risks in PIB and determine whether the targets discussed in Section 2.3.3c are met. These include: 1) risks from ingestion exposure to COPCs in sediments and benthic fauna that serve as food sources; 2) the effects of COPCs on benthic community health; and 3) the risks posed by COPCs that bio-accumulate in fish that serve as a food source for PIB wildlife.

The second and third lines of evidence were evaluated above as part of the benthic invertebrate and fish risk assessments. This section presents the evaluation of the first line of evidence, risks from exposure to COPCs to wildlife that feed on benthic fauna.

COPC data for benthic fauna are not available within PIB. However, exposure of potential wildlife receptors to COPCs in PIB can be estimated using sediment data and exposure models. The exposure assessment, effects assessment and risk characterization for wildlife is presented below.

3.5.1 Exposure Assessment

Exposure of avian and mammalian receptors to chemicals in Presque Isle Bay were estimated using sediment data from near-shore areas with overlying water depths of less than 2 meters. Chemical ingestion exposure of these organisms was expected to occur through food consumption and incidental sediment ingestion, because the chemical accumulation of their prey is expected to be through sediment exposure. Water data were not available for this analysis, but water exposure was expected to be insignificant when compared to exposure from food and sediment ingestion. Exposure was assessed for the following representative species.

Piscivorious Mammals - The mink is the species most represented by piscivorious mammals in PIB. Mink will feed on both fish and aquatic invertebrates, though it is assumed for calculations that the diet of mink is completely of fish. The process described by Battelle (2002) was used to calculate the ingestion rate of piscivorious mammals.

Insectivorious Waterfowl - The mallard duck and spotted sandpiper are the species most represented by insectivorious waterfowl in PIB. The process described by Battelle (2002) was used to calculate the ingestion rate of insectivorious waterfowl. The fraction of diet of insectivorious waterfowl composed of invertebrates was considered to be 75% for calculation of ingestion rate.

Piscivorious bird – The Great Blue Heron represents the wading, piscivorious avian species in PIB. The process described by Battelle (2002) was used to calculate the ingestion rate of the Great Blue Heron.

Chemical exposures of avian and mammalian wildlife receptors were evaluated by estimating daily oral doses. These doses were expressed as milligram chemical per kilogram body weight per day (mg/kg/d). Accordingly, estimates of receptor ingestion rates and body weights were required so cconservative ingestion rates and body weight assumptions required.

To calculate the ingestion rates for wildlife, COPC concentrations needed to be calculated in benthic invertebrates and fish based on the sediment concentrations. The chemical concentrations in fish were calculated based on the methods used by Battelle (2002), which also required the calculation of estimated concentrations in benthic invertebrates.

The estimated concentration of each COPC in benthic invertebrates was calculated using the following equation:

$$C_b=(C_s / f_{OC}) \times BSAF \times fL$$

Where:

C_b = Concentrations of COPC in benthic invertebrates (mg/kg –wet weight)
C_s = Concentration of COPC in sediment (mg/kg dry weight)

f_{OC} = Fraction of organic carbon content of sediment

$BSAF$ = Biota Sediment Accumulation Factor (mg/kg-OC/mg/kg lipid) (Metals assumed value of 1)
fL = Conversion factor to convert lipid-normalized body burden to a wet-weight concentration (mg/kg-lipid/mg/kg-wet-weight) (assumed to equal 0.01)

The estimated concentration of each COPC in fish was calculated using the following equation, assuming fraction of diet of fish composed of benthic invertebrates is one.

$$C_{fs} = (C_b \times IR \times AF)/(GR+ER)$$

Where:

C_{fs}= Estimated COPC concentration in fish from the ingestion of benthic invertibrates (mg/kg-wet-weight)
C_b = Estimated concentration of COPC in benthic invertebrates (mg/kg-wet-weight)
IR = Ingestion rate of fish (kg/kg-day) (Assumed 0.05)
AF = Absorption factor of COPC (Metals assumed value of 1)
GR = Growth rate (equivalent to $0.01 \times (BW)^{-0.2}$
ER = Excretion rate (equivalent to 0.25×IR

Using the measured and estimated concentrations for COPCs in sediment, benthic invertebrates, and fish, the estimated daily intake of each COPC for the Great Blue Heron was calculated using the following equation:

$$DI = [(C_{fs} \times IR_f)+(C_b+IR_b)+(C_s \times IR_s)]/BW$$

Where:

DI = Daily intake (mg/kg-d)
C_{fs}= Estimated concentration of COPC in fish (mg/kg-wet-weight)
IR_f = Ingestion rate of fish by end species (kg/kg-day) (Using EPA 1993)
C_s = Measured concentration of COPC in sediment (mg/kg-dry-weight)
IR_b = Ingestion rate of benthic invertebrates by end species (kg/kg-day) (Using EPA 1993)
C_b = Measured concentration of COPC in benthic invertebrates (mg/kg-dry-weight)
IR_s = Sediment ingestion rate (based on EPA 1993)
BW = Body weight (kg)

3.5.2 Effects Assessment

To study the health of wildlife in the near-shore area of the AOC, the Hazard Quotients for piscivorious mammals (mink), insectivorious waterfowl (mallard duck), probing birds (spotted sandpiper), and piscivorious birds (great blue heron) were analyzed using the process described by Battelle (2002). The hazard quotient is the ratio of the COPCs ingested to the "no observed adverse effect level" (NOAEL) and "lowest observed adverse effect level" (LOAEL), provided by EPA (EPA 2008). Hazard quotients (HQs) were calculated for near-shore sample sites that had an overlying water depth of less than two meters. The spread sheet calculations for the HQs for the COPCs for both the NOAELs and LOAELs for the three representative receptors (mink, mallard duck, and Great Blue Heron) are presented in Attachment 2.

3.5.3 Risk Characterization

The following risk criteria from Battelle (2002) were adopted for the purposes of characterizing risk to wildlife posed by contaminated sediments:

- Low: Samples where HQs for all COPCs were less than 1.
- Medium: Samples where HQs for no more than 3 COPCs were greater than 1 and all HQs were less than 10.
- High: Samples where HQs for more than 3 COPCs were greater than 1 or at least 1 HQ was greater than 10.

Since the HQ is the ratio of the contaminant ingested to an effect level, low risk is desired because it suggests that the amount of contaminant ingested is less than the adverse effect level. These categories were selected on approaches used by Battelle (2002) using a much more robust dataset. The Battelle (2002) approach and target for low risk HQ is assumed useful for assessing relative risks of COPC ingestion to PIB wildlife. It is important to note that, lacking locally collected data on COPC concentrations of potentially ingested fish and benthic invertebrates, the calculated estimates are assumptions, included for relative comparison purposes, and may not reflect local or regional levels of risk. HQ values should only be use for relative risk comparison by species among sample periods and not among species.

The percentages of stations with hazard quotients that meet the criteria for each study are given in Table 3.10. Table 3.10 evaluations include samples from 1990 (n=5), 1992 (n=2), 2002 (n-1), and 2005 (n=6). Figures 3.15 through 3.20 depict the spatial distribution of sediment samples and respective estimated NOAEL and LOAEL risk levels for mink, mallard duck, and Great Blue Heron. A plot of hazard quotients for each study and effect level is given in Figure 3.21.

Table 3.10 shows that, for the two periods of larger samples (1990 (n=5) and 2005 (n=6)), in 1990, the risk criteria for all endpoint species is Low or Medium for both the LOAEL and NOAEL criteria. The risk criteria for 2005 samples for all endpoint species is Low or Medium for both the LOAEL and NOAEL criteria. The relative difference between the two samples finds the 2005 samples with a greater percentage of low risk categorized samples among all wildlife species for both LOAEL and NOAEL than those of 1990. Although the overall sample sizes are relatively small, the calculations do suggest a slight decrease in risk from medium to low between the 1990 and 2005 sample periods.

Table 3.10. Percentage of samples at risk criteria by endpoint species and risk level

Sample Year	Number of Samples	Risk Criteria	Great Blue Heron		Mink		Mallard	
			LOAEL	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL
1990	5	Low	20%	20%	20%	20%	100%	60%
		Med	80%	80%	80%	80%	0%	40%
		High	0%	0%	0%	0%	0%	0%
1992	2	Low	0%	0%	0%	0%	100%	100%
		Med	100%	50%	100%	100%	0%	0%
		High	0%	50%	0%	0%	0%	0%
2002	1	Low	0%	0%	0%	0%	100%	0%
		Med	100%	0%	100%	0%	0%	100%
		High	0%	100%	0%	100%	0%	0%
2005	6	Low	50%	33%	67%	33%	100%	83%
		Med	50%	67%	33%	67%	0%	17%
		High	0	0	0%	0%	0%	0%

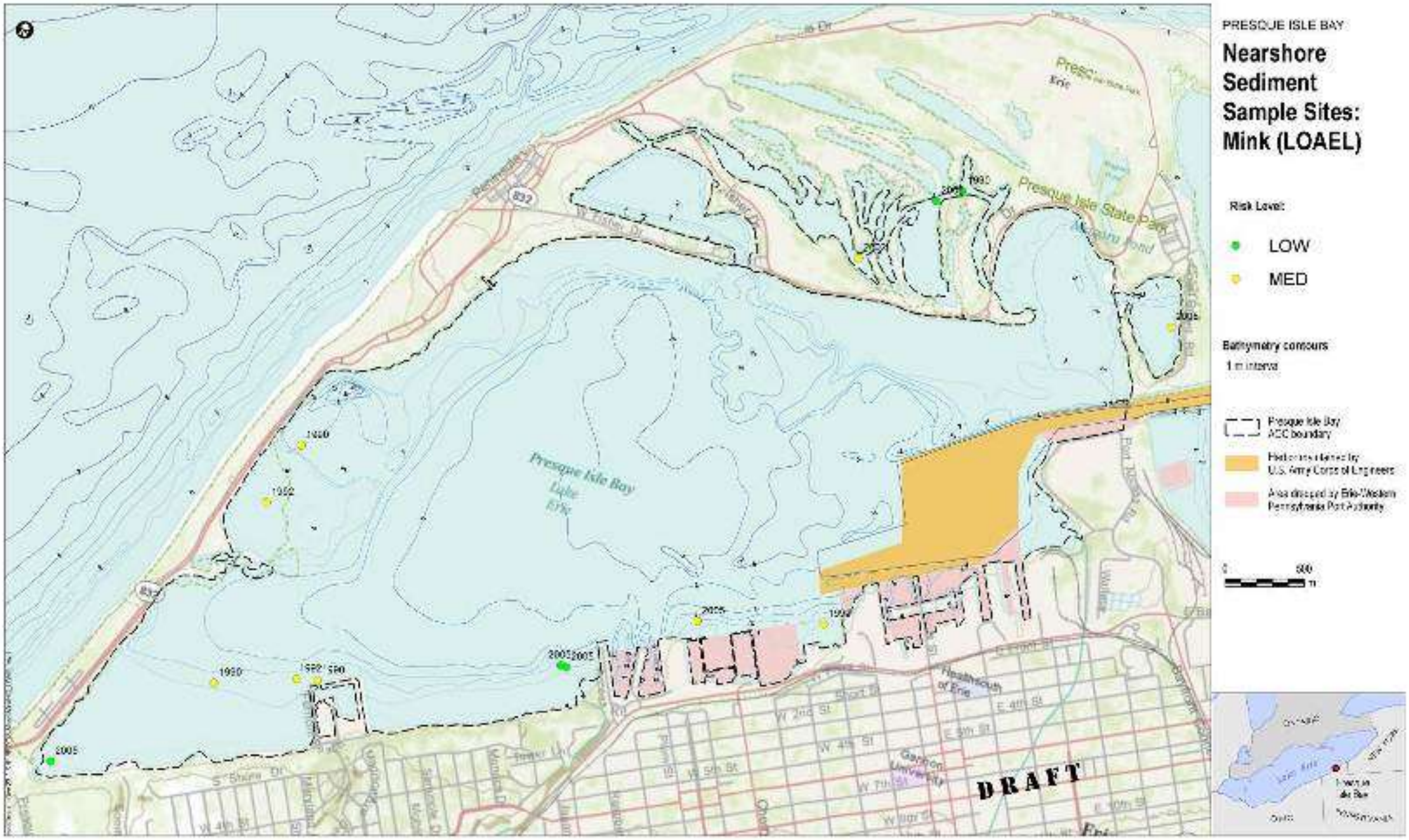

Figure 3.15. Risk levels for Mink at LOAEL toxicity reference value.

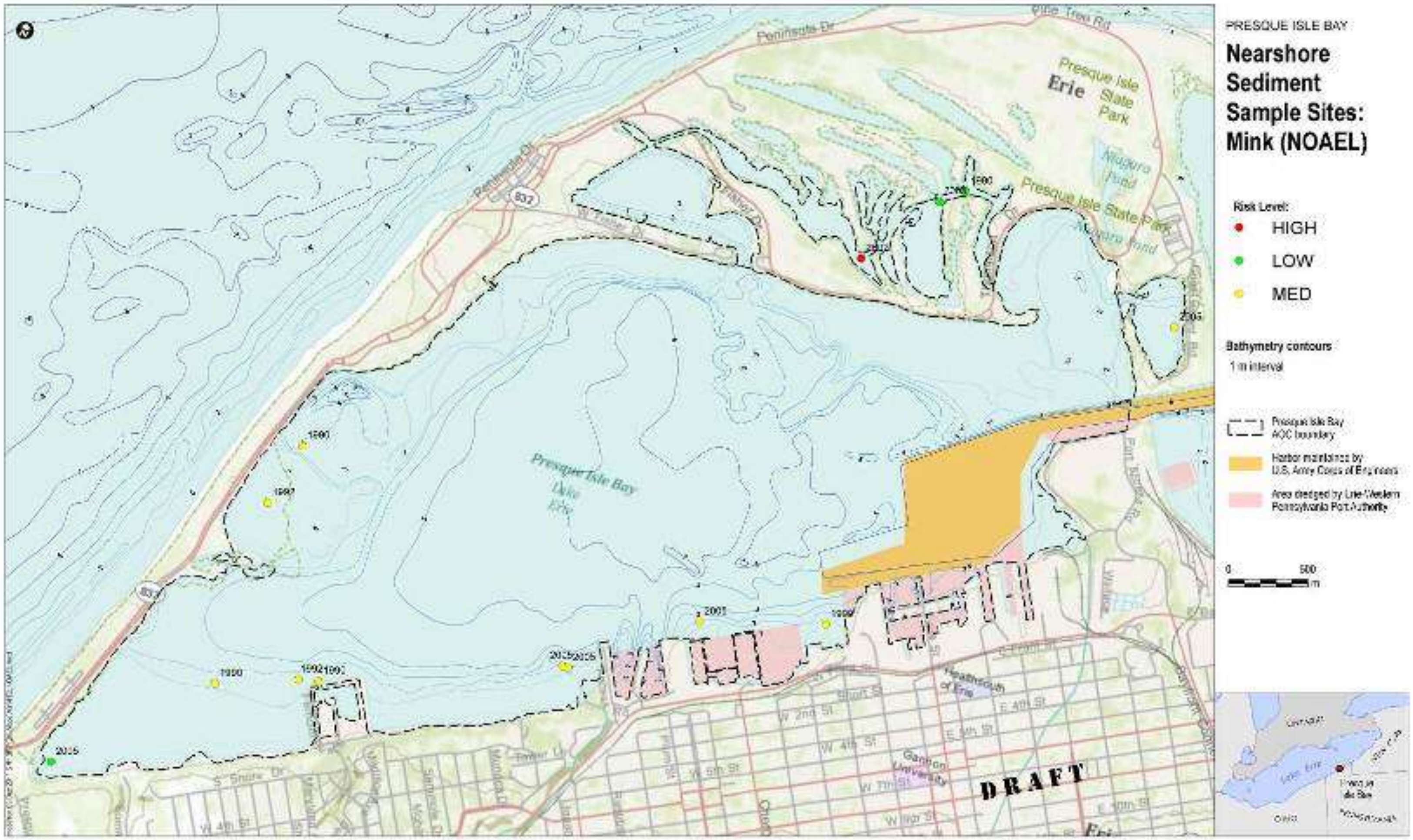

Figure 3.16. Risk levels for Mink at NOAEL toxicity reference value.

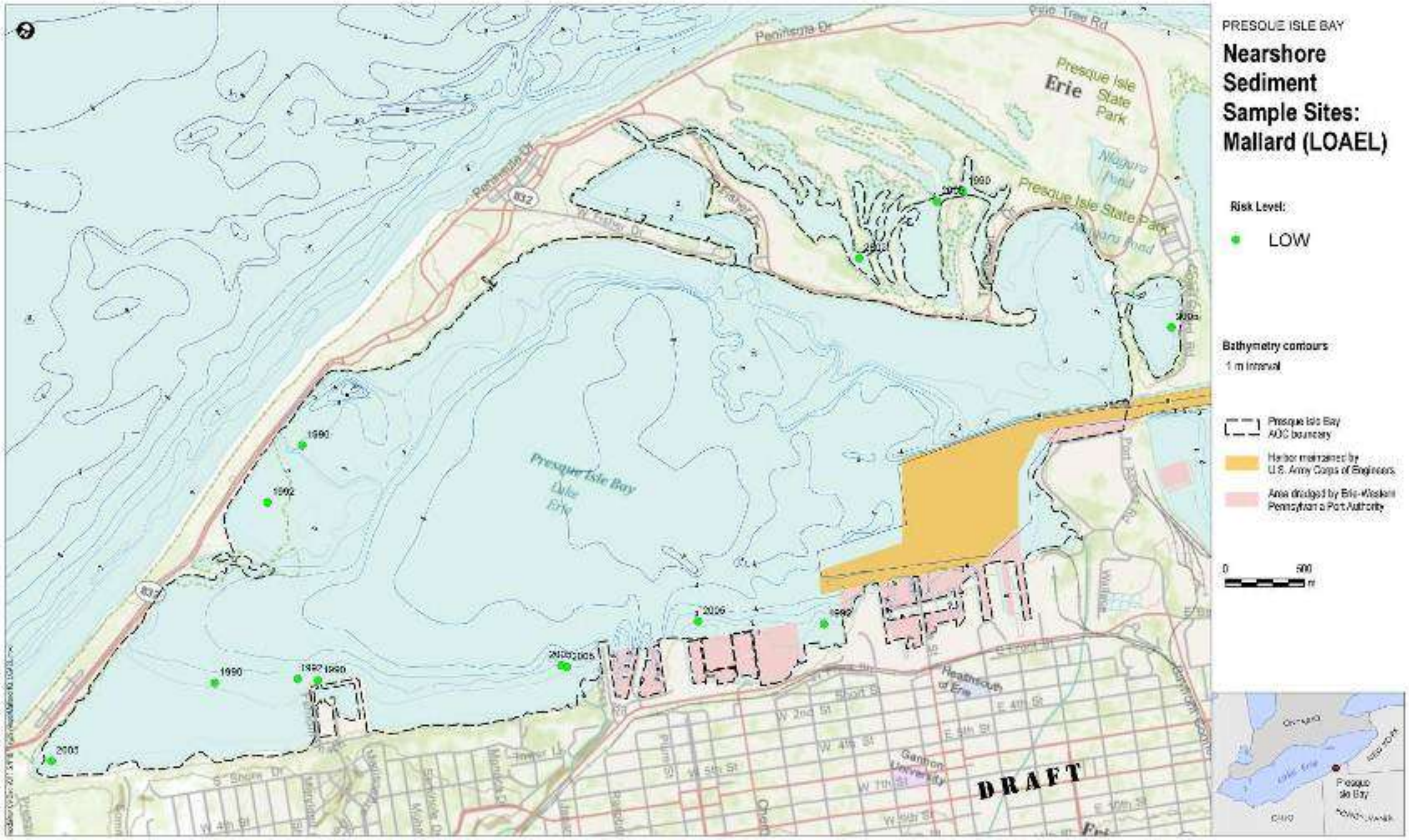

Figure 3.17. Risk levels for Mallard at LOAEL toxicity reference value.

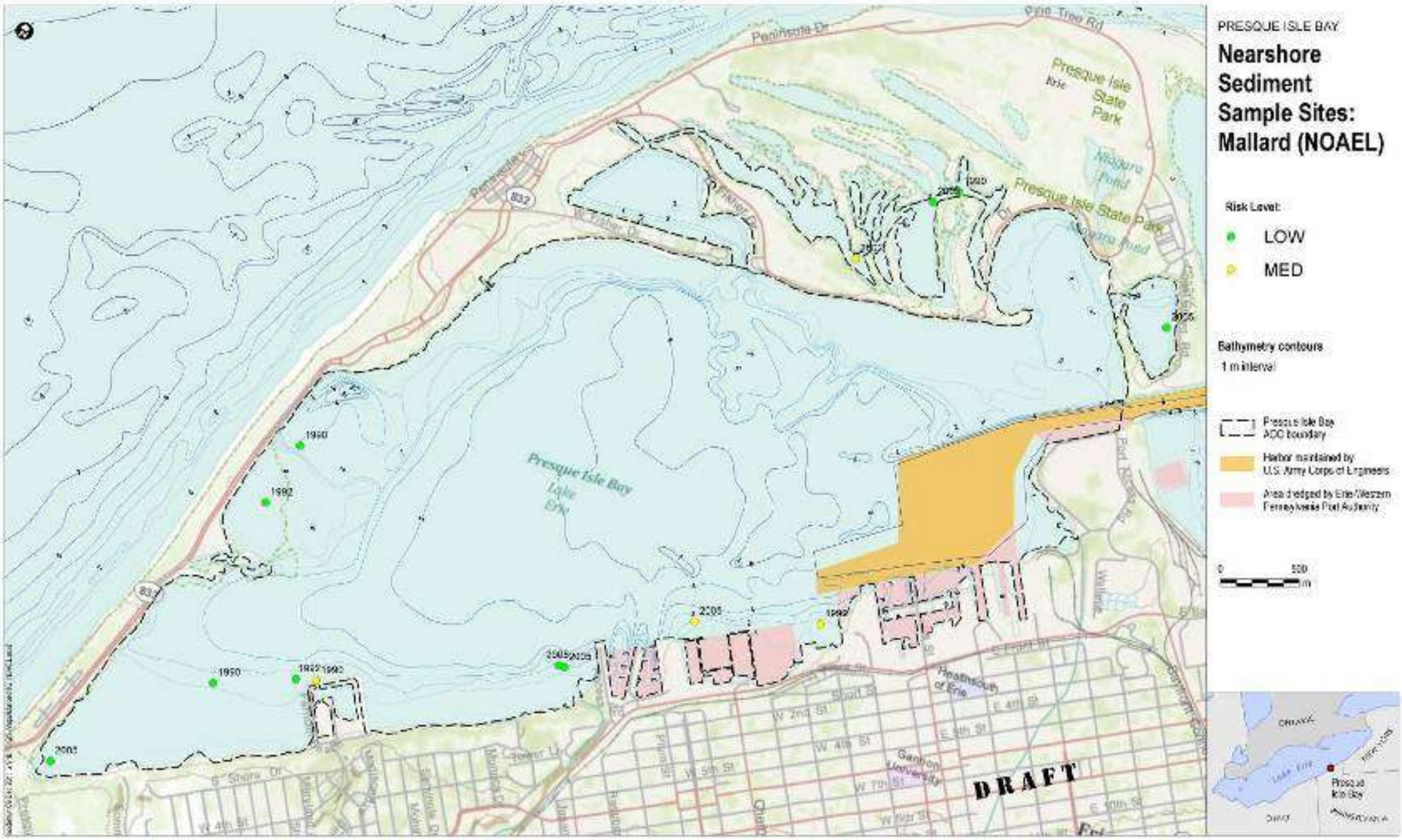

Figure 3.18. Risk levels for Mallard at NOAEL toxicity reference value.

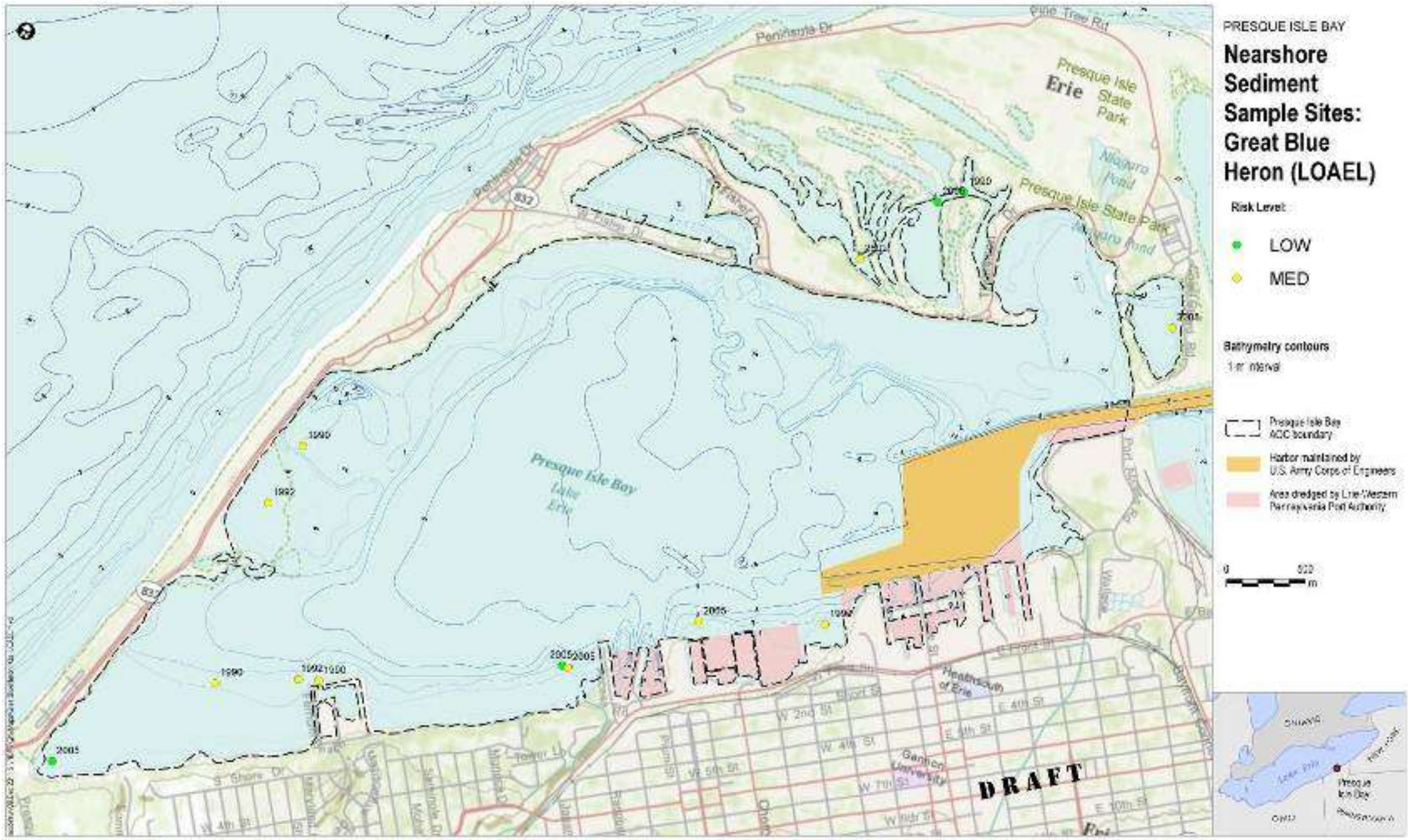

Figure 3.19. Risk levels for Great Blue Heron at LOAEL toxicity reference value.

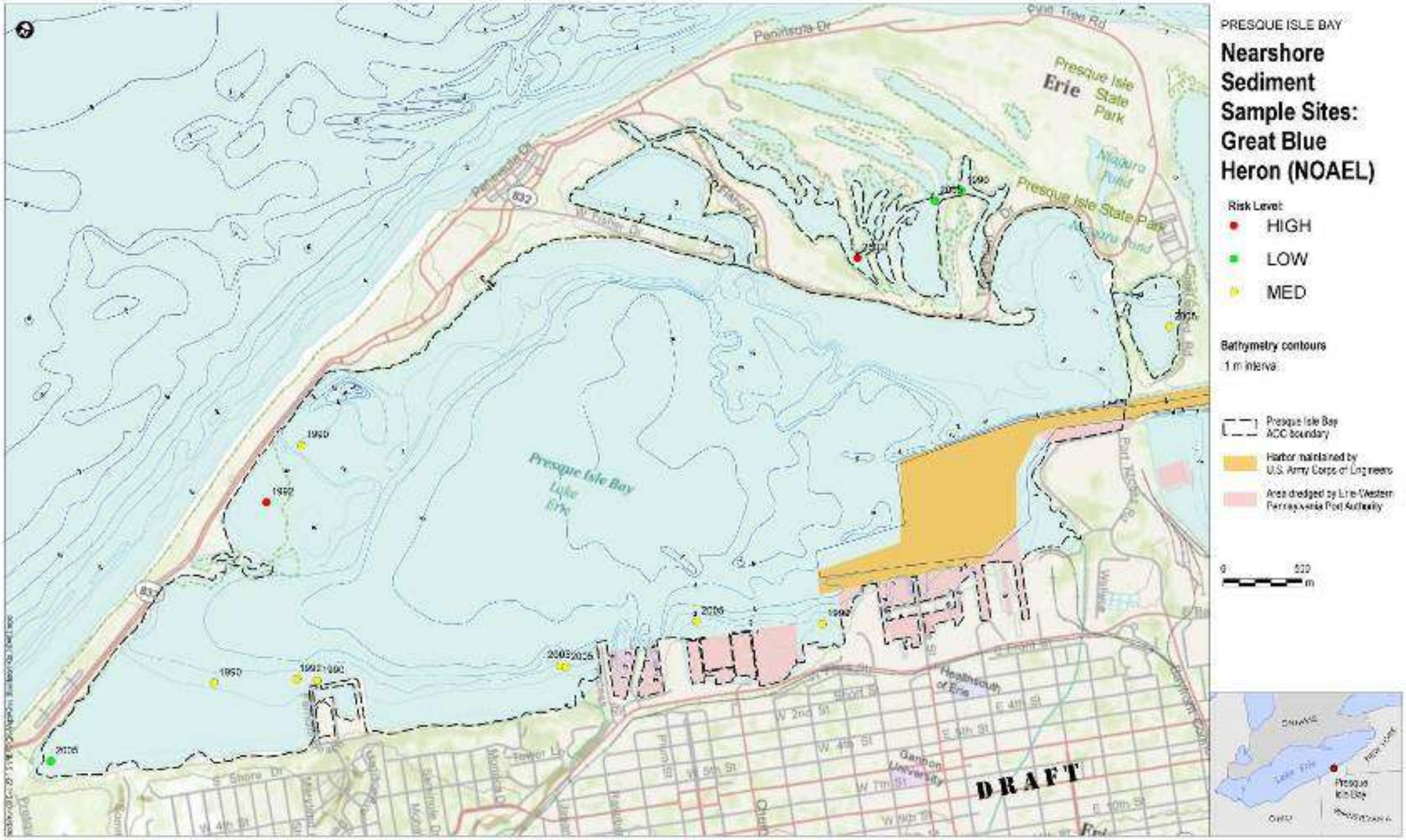

Figure 3.20. Risk levels for Great Blue Heron at NOAEL toxicity reference value.

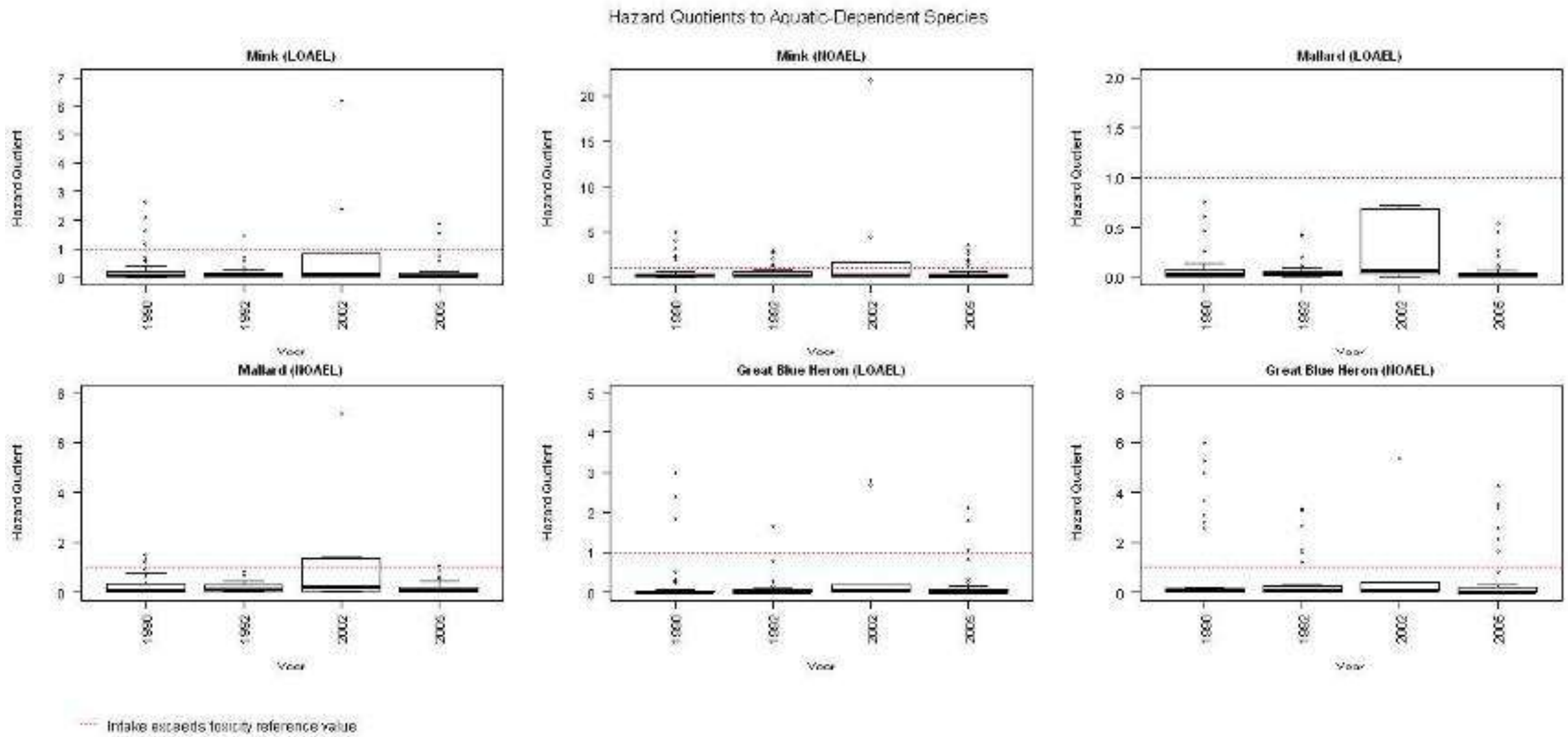

Figure 3.21. Hazard quotients and exceedances of hazard quotients for different receptors from PIB sediments

3.6 RISK SUMMARY

The risk characterization integrates the exposure and effects characterizations to assess whether chemical concentrations (COPCs) are sufficiently high to pose unacceptable risks to ecological receptors. Other authors provide varying levels of direct or indirect evaluations of risk on receptors within PIB (Attachment 2). It should be emphasized that this screening-level ecological risk assessment, where possible, incorporated conservative estimates where uncertainties were apparent, which is typical for a screening analysis (i.e., risks are likely to be overestimated rather than underestimated). The chemicals identified as chemicals of potential concern (i.e., COPCs) may be evaluated further in site-specific assessments to further characterize the risks they pose. The following sections present the risk characterizations within the PIB ecosystem from both previous investigations (Section 2) and primary evaluations of available data (below).

The evaluation of the target objectives conducted for this SLERA has been compiled to establish a weight of evidence supporting the previously posed question of:

Do legacy contaminants (COPCs) continue to pose a risk to ecosystem receptors within Presque Isle Bay?

Below (Table 3.11) is a summary of how the various findings supported the evaluation of the PIB ecosystem objectives.

Objectives	**Benthic Invertebrate Community**					**Quality Fishery**				**Near-shore Habitats (Wildlife)**		
Target	**90% of samples meeting criterion**					**Water Quality**	**Benthic Invertebrate Health (Prey Base)**	**Bioaccuumulation (Tissue Samples)**	**Tumor Lesion Effect (Brown Bullead)**	**COPC Exposure Risk (Exposure Models)**	**Bioaccumulation (Fish Tissue Samples)**	**Benthic Invertebrate Health (Prey Base)**
Metrics	**PEC-Q**	**SEM-AVS**	**SEM_AVS foc**	**ESB-TUs**	**Sed. Tox. And Surv.**							
Studies												
Diz (2002)		Y			N							
Diz (2005)		Y										
Kemble et al. (2006)					Y							
MacDonald (2008)	N	Y	Y	Y	Y		Y					Y
Pyron et al. (2001)									Y			
SLERA	N	Y	Y	U	N	Y	Y	Y	U	Y	Y	Y

Y = Supports Target Metric; N = Does Not Support Target Metric; U = Inconclusive Consistency

Table 3.11. PIB Ecosystem Objectives, targets and metrics evaluated by previous and current investigations.

(White boxes depict PIB studies using primary source data to evaluate targets and/or metrics, Gray boxes depict areas that are not applicable)

3.6.1 Weight of Evidence

1) Surface sediment COPCs appear to be the primary chemical stressor in this system, although habitat (substrate) and invasive species may be additional stressors on the ecological community that may be challenging to tease apart.

2) The potential risk of COPC exposure benthic invertebrates across PIB are generally low based on whole sediment toxicity tests. Isolated areas may pose a moderate to high risk of exposure.

3) Benthic invertebrate exposure risk has decreased through time and are generally meeting toxicity targets.

4) The probable effect concentration (PEC) targets are generally met across PIB for most COPCs. Exceedences do occur for metals like barium and cadmium and for some PAHs. Studies focused on high concentration areas tend to exceed PEC in most cases but skew the baywide results.

5) Metals bioavailability across the PIB appears to be decreasing through time, with recent samples meeting low toxicity thresholds.

6) The quality fishery objective within PIB are supported by good water quality, a low risk of prey base (benthic invertebrates) exposure to COPCs, and fish tissue concentration of monitored compounds that are similar to background levels.

7) Water quality conditions are based on qualitative evaluations and fish tissue concentrations for monitored contaminants (e.g., mercury and PCBs) and are similar to or better than other Lake Erie levels.

8) Near-shore sediment habitats suggest that ingestion exposure risks to wildlife are moderate to low, and the elevated surface sediment concentrations of PAHs and metals (dry weight) in PIB tend to be in the vicinity of the docks and shipping channel.

Overall, it appears that the targets supporting the PIB ecosystem are being met. Gaps in data to definitively describe all targets and metrics exist, but the current weight of evidence suggests that the risk to ecosystem receptors within PIB is improving through time currently rates low to moderate risk.

4. UNCERTAINTIES AND CONCLUSIONS

4.1 UNCERTAINTIES

A discussion of uncertainties is important in any risk assessment and can be critical in making risk management decisions. A consideration of uncertainties is also imperative in using the lines of evidence approach discussed above. For example, the lines of evidence need to be balanced by considering the amount of uncertainty associated with each (U.S. EPA 1998). This screening level assessment relied entirely on previously conducted investigations and data collected by other organizations and agencies, so it is assumed that standard QA/QC protocols of data design, collection, processing, and analysis were maintained.

The CSM is intended to define the linkages between stressors, potential exposure, and predicted effects on ecological receptors. Potential uncertainties arise from lack of knowledge regarding ecosystem functions, failure to adequately address spatial and temporal variability in the evaluations of sources, fate and effects, omission of stressors, and overlooking secondary effects (USEPA 1998).

Of the CSM components, the identification of exposure pathways probably represents the primary source of uncertainty in the conceptual model. In this assessment, supported by MacDonald (2008), it was assumed that exposure to whole sediments represents the most important pathway for exposing benthic invertebrate communities and macrofauna that have a benthic component in their food web to COPCs (i.e., as the benthic invertebrates associated with benthic habitats likely play key ecological functions, and contaminant concentrations are likely to be highest in this medium). However, receptor communities may also be exposed to COPCs in the water column, but this pathway was not examined and data supporting an examination of this pathway are lacking. As result, this potential pathway has not been considered in this risk analysis to the ecosystem, and may be underestimated if this represents a COPC route.

The exposure assessment is intended to describe the actual or potential co-occurrence of stressors with receptors. As such, the exposure assessment identifies the exposure pathways and the intensity and extent of contact with stressors for each receptor or group of receptors at risk. There are a number of potential sources of uncertainty in the exposure assessment, including measurement errors, extrapolation errors, and data gaps (MacDonald 2008).

The range of investigations, their scales, methods and results increase the uncertainty of results as direct comparisons among investigations. Most of the included investigations were not designed to support an ecological risk assessment, thus a screening level assessment has been applied. The range, focus and site selection strategies of investigations conducted in PIB complicate the ability to make “apples to apples” comparisons among years to quantify trend and spatial variability.

PIB is a dynamic system. The system contains areas of active erosion, deposition and resuspension influenced by relatively small contributions of watershed-level sediment inputs, dredging for navigation and recreation boating, and seiche effects that complicate any analysis of legacy inputs. The erosive and resuspension dynamics as sources of exposure remain to be understood in the system.

Wherever possible, conservative assumptions were used in estimating receptor exposures to chemicals and in identifying toxicity thresholds. The largest sources of data for the screening-level assessment were the chemistry data for sediment. These data were used to estimate whether individual chemicals, and in some cases classes of chemicals, were present at sufficiently high concentrations to pose a potential risk to ecological receptors. This approach uses site-specific chemistry data, but assumptions are required in estimating the magnitude of exposure to biota.

Limited fish tissue samples were available for this study, and for those samples available, the constituent data were for mercury, and none listed the COPCs within Presque Isle Bay. The levels of COPCs used in this screening-level assessment within fish tissue remain unknown.

Fish tumor science is still evolving, but the evidence thus far suggests that external tumors and the frequency of external tumor rates are less strongly linked to legacy contaminants than liver tumors and liver tumor frequencies. External and internal tumor frequencies do not necessarily support one another. It may be years before scientists fully understand the causes or relationships of COPCs to external tumors and frequency.

There is uncertainty associated with the calculation of a hazard quotient (HQ) and its strength of association with toxicity to an endpoint. One level of uncertainty is associated with the feeding areas associated with each endpoint. The calculations were conservative and assumed that a specific species feeds only in Presque Isle Bay throughout the whole year. This may be a reasonable assumption for the mink, but may not be for more mobile species like the mallard duck or great blue heron. The calculations also did not take into account the complexities of the diets of the endpoint species. In reality, the species evaluated most likely obtain their food from a variety of sources. Though their diets may be focused on benthic invertebrates or fish, the types of invertebrates or fish being ingested will have varying levels of contamination for each prey species.

4.2 CONCLUSION

The purpose of this study was to explore the potential to remove the fish tumor BUI for PIB on the basis of an examination of the effects of fish tumor suspected stressors (essentially surface sediment COPC concentrations) on other components of the ecosystem. To make that assessment, a screening-level ecological risk analysis based on a weight-of-evidence of existing data for PIB has been conducted as a surrogate for a formal risk assessment of the exposure pathways that are leading to the occurrence of external fish tumors. The weight-of-evidence for sediment COPC effects on receptors conducted in this study, suggest that exposure to surface sediment

COPCs are not posing a significant adverse impact on the overall PIB ecosystem. These results should be used in conjunction with the incidence of tumor rates within PIB and an overall assessment of ecosystem effects from COPCs. At present, the combination of data suggests that the incidence of internal fish tumors in PIB is not significantly different from reference sites and the combined information may provide sufficient justification for removing the fish tumor BUI from PIB. Of course, moderately elevated external skin lesions remain in PIB benthic fish, and additional research is needed to establish the stressor or stressors (e.g., sediment physical properties, exposure to viruses) that are causing this result.

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ATTACHMENTS

ATTACHMENT 1 SUMMARIES OF PIB SUPPORTING PAPERS

ATTACHMENT 2 - SPREADSHEET CALCULATIONS OF HAZARD QUOTIENTS FOR WILDLIFE RISK ASSESSMENT