Appendix E:
Development of Preliminary Remediation Goals

LOWER EIGHT MILES OF THE LOWER PASSAIC RIVER
DEVELOPMENT OF PRELIMINARY REMEDIATION GOALS

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1 HUMAN HEALTH PRELIMINARY REMEDIATION GOALS

A human health risk assessments (HHRA) was conducted to determine the potential for unacceptable risks following exposure to contaminated environmental media in the lower eight miles of the Lower Passaic River. The risk assessment is provided in Appendix D. The following sections summarize the technical approaches employed to develop the preliminary remediation goals (PRGs) to support the Focused Feasibility Study (FFS). Health protective PRGs were developed for both sediment and fish media; the latter are provided for use during a potential long-term monitoring phase following implementation of a remedial alternative. Chapter 2 of the FFS evaluates these risk-based values along with background concentrations and presents selected PRGs.

The HHRA was conducted by estimating carcinogenic risks and noncarcinogenic health hazards for exposures to an adult angler/sportsman and other family members (*i.e.*, adolescent and child) from ingestion of self-caught fish and blue crab from the lower eight miles of the Passaic River (FFS Study Area). Several classes of chemicals of potential concern (COPCs) were identified in the Pathways Analysis Report (PAR) (Battelle, 2005), including various metals, pesticides, dioxins, polychlorinated biphenyls (PCBs) and volatile organic compounds/semi-volatile organic compounds. For human health, a subset of the COPCs identified in the PAR that were considered to be most bioaccumulative, most persistent in the environment and most toxic to human receptors was evaluated in the baseline HHRA. These COPCs included:

- Dioxins/furans (D/F; as 2,3,7,8-tetrachlordibenzo-p-dioxin toxic equivalent quotient [TCDD TEQ[1]]);
- Total non-dioxin-like PCBs (sum non-dioxin-like congeners);
- PCBs (12 dioxin-like congeners as TCDD TEQ);
- Dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyltrichloroethane (DDT);
- Dieldrin;

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[1] Consistent with the toxic equivalency approach (van den Berg *et al.*, 2006; USEPA 2010), the toxicological basis for the PRGs for D/F and PCB compounds with dioxin-like toxicity is 2,3,7,8-TCDD. TCDD TEQ refers to the combined equivalency associated with all aryl hydrocarbon receptor (AhR) mediated toxicity.

- Total chlordane; and,
- Mercury (as methylmercury).

The HHRA estimated the magnitude of potential cancer risks and noncancer health hazards under baseline current and baseline future modeled conditions assuming no remediation or institutional controls. For baseline current conditions, exposures were calculated using the analytical results of tissue samples collected from the FFS Study Area in 2009. Consistent with United States Environmental Protection Agency (USEPA) guidance (USEPA, 1989), these tissue concentrations were assumed to remain constant throughout an organism's lifetime and did not consider any attenuation or degradation of the chemical that may occur over time. For baseline future conditions, exposures were calculated using modeled annual average projections of future concentrations in sediment that consider natural attenuation and degradation over time (see Appendix B for information on the model used to predict future contaminant concentrations).

The baseline current HHRA evaluated cancer risks and noncancer health hazards from each COPC based on the reasonable maximum exposure (RME) and a central tendency exposure (CTE) to describe the magnitude and range of exposure for the receptor groups. The objective of providing both the RME and CTE exposure cases is to bound the risk/hazard estimates, but decisions are based on the RME consistent with the National Contingency Plan (NCP) (USEPA, 1990). As such, results of the RME exposures are summarized below (Appendix D contains the results of both the RME and CTE exposures).

The RME cancer risks associated with baseline current conditions are summarized in Table 1-1. The calculated total RME cancer risks for the adult sportsman/angler[2] are 5×10^{-3} and 2×10^{-3} for ingestion of fish and crab, respectively[3], which exceed the NCP risk range of 10^{-4} to 10^{-6}. TCDD TEQ (D/F), TCDD TEQ (PCBs), and Total non-dioxin-like PCBs are the primary contributors to the combined risk above 10^{-3} for ingestion of both fish and crab. Approximate contributions to total risk from fish are 70 percent from TCDD TEQ (D/F), 11 percent from TCDD TEQ (PCBs), 16 percent from Total non-dioxin-like PCBs and 2 percent from dieldrin.

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[2] Estimated for a 30-year exposure duration by summing the risks for the adult (based on 24-year exposure) and the child (based on 6-year exposure).

[3] The risks in Tables 1-1 and 1-3 are presented in scientific notation such that, for example, 5×10^{-3} = 5E-03.

For ingestion of crab, TCDD TEQ (D/F) comprises 82 percent of the risk, while TCDD TEQ (PCBs) and Total non-dioxin-like PCBs contribute 12 percent and 5 percent, respectively, and dieldrin contributes 1 percent to the total risk. The ingestion risks for the adolescent receptor are 2×10^{-3} and 6×10^{-4} for fish and crab, respectively. RME cancer risks are above the NCP risk range of 1×10^{-4} (one in ten thousand) to 1×10^{-6} (one in one million).

The noncancer RME health hazard indices (HIs[4]) for baseline current conditions are summarized in Table 1-2. For ingestion of fish, the HIs are 126 for the adult, 113 for the adolescent, and 195 for the child. For ingestion of crab, the HIs are 43 for the adult, 38 for the adolescent, and 67 for the child. TCDD TEQ (D/F), TCDD TEQ (PCBs), and Total non-dioxin-like PCBs are the primary contributors to the hazards for both fish and crab consumption, with individual hazard quotients (HQs) above 1 for each receptor. The HQs for ingestion of methylmercury in fish are 2 for the adult and adolescent receptors and 3 for the child receptor. The USEPA goal of protection of a noncancer HI equal to 1 is exceeded for the fish and crab RME scenarios.

The RME cancer risks associated with baseline future modeled conditions are summarized in Table 1-3. The calculated total RME cancer risks for the adult sportsman/angler[5] are 4×10^{-3} and 2×10^{-3} for ingestion of fish and crab, respectively. The ingestion risks for the adolescent receptor are 1×10^{-3} and 6×10^{-4} for fish and crab, respectively. TCDD TEQ (D/F), TCDD TEQ (PCBs), and Total non-dioxin-like PCBs are the primary contributors to a combined risk greater than 10^{-4} for ingestion of fish and crab, with individual cancer risks at or above the 10^{-4} risk level for TCDD TEQ (D/F) and TCDD TEQ (PCBs) for each receptor. Approximate contributions from the primary COPCs to total risk for the the adult sportsman/angler[4] from fish are 50 percent from TCDD TEQ (D/F), 37 percent from TCDD TEQ (PCBs), and 13 percent from Total non-dioxin-like PCBs. For ingestion of crab, TCDD TEQ (D/F) comprises 45 percent of the risk, while TCDD TEQ (PCBs) and Total non-dioxin-like PCBs contribute 49 percent and 6 percent, respectively, to the total risk. The RME cancer risks are above the NCP risk range of 1×10^{-4} to 1×10^{-6}.

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[4] The ratio of the intake to the reference dose for an individual chemical is the hazard quotient (HQ), while the hazard index (HI) is the sum of chemical-specific HQs.

[5] Estimated for a 30-year exposure duration by summing the risks for the adult (based on 24-year exposure) and the child (based on 6-year exposure).

The RME noncancer HIs for future modeled conditions are summarized in Table 1-4. For ingestion of fish, the RME HIs are 90 for the adult, 87 for the adolescent, and 163 for the child. For ingestion of crab, the HIs are 40 for the adult, 39 for the adolescent, and 71 for the child. TCDD TEQ (D/F), TCDD TEQ (PCBs), and Total non-dioxin-like PCBs are the primary contributors to the excess hazard for both fish and crab consumption, with individual HQs above 1 for each receptor. The USEPA goal of protection of an HI equal to 1 is exceeded for the fish and crab RME scenarios.

The HHRA under baseline current and future conditions determined that total cancer risks are above the NCP risk range of 10^{-4} to 10^{-6} and individual noncancer health hazards are above a HQ of 1. As shown in Tables 1-1 and 1-3, the following COPCs have individual cancer risks above 10^{-4}:

- TCDD TEQ (D/F)
- TCDD TEQ (PCBs)
- Total non-dioxin-like PCBs

As shown in Tables 1-2 and 1-4, the following COPCs have individual health hazards above a HQ of 1:

- TCDD TEQ (D/F)
- TCDD TEQ (PCBs)
- Total non-dioxin-like PCBs
- Methylmercury

Note that the HQ for methylmercury was greater than 1 for ingestion of fish only (Tables 1-2 and 1-4).

1.1 Calculation of Preliminary Remediation Goals for Ingestion of Fish and Blue Crab

Human health risk-based tissue PRGs were calculated for fish and crab for those COPCs individually exceeding the NCP goal of protectiveness of 10^{-4} for cancer risk or 1 for noncancer health hazards: TCDD TEQ (D/F), TCDD TEQ (PCBs), Total non-dioxin-like PCBs, and methylmercury. A tissue PRG based on carcinogenic effects was calculated for Total non-dioxin-like PCBs, but not for TCDD TEQ (PCBs), for two reasons. First, separate tissue PRGs for Total non-dioxin-like PCBs and TCDD TEQ (PCBs) would not significantly differ because the estimated carcinogenic risks determined during the HHRA for Total non-dioxin-like PCBs and dioxin-like PCB congeners are comparable. Second, any remedial action based on PRGs for Total non-dioxin-like PCBs would address the presence of the dioxin-like PCB congeners.

The tissue PRGs were calculated following Risk Assessment Guidance for Superfund Part B (USEPA, 1991). For this analysis, the exposure assumptions used in the HHRA were used in the calculation of the PRGs, including annual adult ingestion rates of 34.6 grams per day (g/day) for fish and 20.9 g/day for crab (USEPA, 2012a). The ingestion rate (IR) is the amount of fish or crab an individual consumes on a daily basis (units g/day) based on the average reported consumption rate in one year (365 days per year [days/year]). An annual IR of 34.6 g fish/day equates to approximately 56 eight-ounce fish meals per year (34.6 g/day × 365 days/year, assuming a portion size of eight ounces, or 227 grams [USEPA, 2011]). An annual IR of 20.9 g crab/day equates to approximately 34 eight-ounce crab meals per year (20.9 g/day x 365 days/year, assuming a portion size of 8 ounces).

For development of the tissue PRGs, the IR is based on the amount of fish (in grams) consumed at one meal. USEPA (2011; 2000) and New Jersey Department of Environmental Protection (NJDEP, 2012) have identified a value of 8 ounces (227 grams) of uncooked fish fillet per 70-kg consumer body weight as an average meal size for adults in the general population. USEPA recommends that the same default value for meal size be used for shellfish (USEPA, 2000). PRGs are designed to be protective of the RME individual and, therefore, no cooking loss was assumed for calculation of the tissue PRGs (see Appendix D).

Calculations. Equations used to derive tissue PRGs for carcinogenic and noncarcinogenic effects are provided below as Equations 1 and 2, respectively. These equations are the same equations used in the HHRA (refer to Appendix D) to calculate the RME chemical intake from ingesting fish/crab and to estimate cancer risk and noncancer health hazards. The equations have been rearranged to solve for the biota tissue concentration (C_{biota}) using the NCP target risk range of 1×10^{-4} to 1×10^{-6} and a target hazard quotient (THQ) for noncarcinogenic effects of 1[6]. USEPA (1991) states that an appropriate point of departure for remediation of carcinogenic risk is a concentration that corresponds to a risk of 10^{-6} for one chemical in a particular medium; however, concentrations corresponding to the other risk levels addressed in the NCP (*e.g.*, 10^{-5} and 10^{-4}) also have been calculated to provide a range of tissue PRGs to assist in the risk management decision process. Table 1-5 provides a summary of the exposure parameter definitions and values.

Toxicity criteria were selected according to the USEPA (2003) Office of Solid Waste and Emergency Response (OSWER) Directive 9285.7-53, which recommends a hierarchy of human health toxicity values for use in risk assessments at Superfund sites. The hierarchy is as follows: (1) USEPA's Integrated Risk Information System (IRIS); (2) USEPA's Provisional Peer-Reviewed Toxicity Values (PPRTV) (Office of Research and Development, National Center for Environmental Assessment, Superfund Health Risk Technical Support Center); and (3) other sources of information, such as toxicity values from the California Environmental Protection Agency (CalEPA), the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs) for noncarcinogenic constituents, and USEPA's Health Effects Assessment Summary Tables (HEAST). Oral toxicity values, such as the cancer slope factor (CSF) and reference dose (RfD), are chemical-specific and are provided in Table 1-6 for each of the COPCs.

USEPA released a final Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments, Volume 1 (USEPA, 2012b) in February 2012. The document provides hazard identification and dose-response information on 2,3,7,8-TCDD, the most up-to-date analysis of

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[6] A target HQ of 1 was used for each of the COPCs because the health endpoints of dioxin, PCBs, and methylmercury are distinctly different.

noncancer health effects from 2,3,7,8-TCDD exposure and a RfD for noncancer health assessment. USEPA has not yet completed Reanalysis, Volume 2, which will contain the full dioxin cancer assessment. In the absence of Volume 2, a Tier 3 toxicity value was used to evaluate dioxin exposures. A range of toxicity values meeting the Tier 3 criteria include:

a. CalEPA Office of Environmental Health Hazard Assessment (OEHHA) value of 130,000 mg/kg-day^{-1}, from its 2009 "Technical Support Document for Describing Available Cancer Potency Factors".
b. CalEPA OHHEA value of 770,000 mg/kg-day^{-1} from the 2010 "Public Health Goals of Chemicals in Drinking Water" developed by its Pesticide and Environmental Toxicology Branch. This CSF is based on the latest National Toxicology Program study in female rats and a new multisite cancer potency factor calculation, derived using updated methodology which, according to OEHHA, is considered to represent a more accurate estimate of potential human cancer risk.
c. USEPA's Office of Health and Environmental Assessment value of 156,000 mg/kg-day^{-1} based on the "Health Assessment Document for Polychlorinated Dibenzo-p-Dioxins" (USEPA, 1985).
d. USEPA's HEAST (1997b) value of 150,000 mg/kg-day^{-1}.

The value of 150,000 mg/kg-day^{-1} was selected to assess the carcinogenic effects from exposure to TCDD TEQ (D/F) in this document to be consistent with earlier USEPA assessments (*e.g.*, Hudson River [TAMS Consultants, Inc., and Gradient Corporation, 2000]; Housatonic River [Weston Solutions, 2005]; Centredale Manor Woonasquatucket River [USEPA Region 1, 2005]). The selection of this value is preferred because of the incidence of all significant tumors combined, rather than based on the incidence of liver tumors alone as is the case with the CalEPA CSF. As discussed above, USEPA released the final *Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments*, which included an oral RfD of 7×10^{-10} mg/kg-day for 2,3,7,8-TCDD (USEPA, 2012). That RfD is used here to assess the noncancer effects from exposure to TCDD TEQ (D/F) and is also the oral RfD provided in IRIS.

In February 2012, USEPA released the final noncancer dioxin reassessment and published an oral RfD of 7×10^{-10} mg/kg-day for 2,3,7,8-TCDD in IRIS, which was used to calculate the noncancer hazard-based tissue PRGs for TCDD (TEQ) and TCDD (PCBs) (USEPA, 2012b).

While oral RfDs are available on IRIS for Aroclor 1016 and Aroclor 1254, the RfD for Aroclor 1254 was used to calculate the noncancer hazard-based tissue PRGs for Total non-dioxin-like PCBs because the bioaccumulation of PCBs is more consistent with the more heavily chlorinated Aroclor 1254.

For carcinogenic effects:

$$C_{\text{biota}} = \frac{\text{BW x AT x TR}}{\text{ED x EF x IR x FI x CF x CSF}} \qquad \text{Equation 1}$$

For noncarcinogenic effects:

$$C_{\text{biota}} = \frac{\text{BW x AT x THQ}}{\text{ED x EF x IR x FI x CF x } {}^{1}\!/_{\text{RfD}}} \qquad \text{Equation 2}$$

Calculated Tissue PRGs. The tissue PRGs developed for the adult angler who consumes fish or crab are summarized in Table 1-7. When available data indicate that a COPC is associated with both carcinogenic and noncarcinogenic health effects, as is the case for TCDD TEQ and Total non-dioxin-like PCBs, PRGs based on both types of effects were calculated. For these COPCs, it is recommended that the toxicological effect resulting in the more conservative PRG be used to be protective of both types of health effects.

Tissue PRGs calculated for consumption by an adult angler are generally lower than tissue PRGs calculated for consumption by adolescents and children. For example, the cancer risk-based fish tissue PRGs for TCDD TEQ and Total non-dioxin-like PCBs *(i.e.*, the primary risk/hazard drivers for the site) for an adult angler are 0.00004 ng/g and 3 ng/g, respectively, at the 1×10^{-6} risk level. Corresponding fish tissue PRGs for an adolescent are 0.0001 ng/g and 7 ng/g, respectively, and for a child are 0.0001 ng/g and 8 ng/g, respectively. The adult noncancer hazard-based fish tissue PRGs for TCDD TEQ and Total non-dioxin-like PCBs are 0.001 ng/g and 40 ng/g, respectively. The fish tissue PRGs for an adolescent are 0.002 ng/g and 45 ng/g, respectively, and for a child are 0.0009 ng/g and 30 ng/g, respectively. Although the child noncancer hazard-based fish tissue PRGs are lower than those of the adult, they are greater than the cancer risk-based tissue PRGs for the adult.

1.2 Interim Biota Tissue PRGs

Statewide fish and crab consumption advisories established by NJDEP and the State Department of Health and Senior Services (NJDHSS) may indicate “do not eat” or “do not eat more than one meal per week, one meal per month, four meals per year, or one meal per year”, where a meal is defined as an 8-ounce serving (NJDEP and NJDHSS, 2012). Advisories are issued for two populations: the general population and high-risk individuals. The latter includes infants, children, pregnant women, nursing mothers and women of child-bearing age. The State does not issue advisories for TCDD TEQ or PCBs for meal frequencies less than monthly for high-risk individuals due to concerns with ingestion of single high doses of contaminants. Therefore, tissue PRGs based on monthly fish and crab consumption rates were calculated for comparison purposes and listed in Table 1-8. These tissue PRGs are protective at fish or crab consumption rates of 12 eight-ounce meals per year (*i.e.*, one meal every month) at a 10^{-6} risk. These PRGs may be used during post-remediation monitoring in order to evaluate if contaminant concentrations are decreasing toward PRGs as expected. Attaining such interim tissue concentrations might facilitate the relaxation of the fish and crab consumption advisories as conditions in the FFS Study Area improve. Tissue PRGs derived for consumption of 56 fish meals per year and 34 crab meals per year are also listed in Table 1-8 for comparison purposes.

1.3 Sediment PRGs Based on Tissue PRGs

Sediment concentrations (*i.e.*, PRGs) required for biota to meet the risk-based tissue PRGs were estimated based on the results of regression analyses conducted to develop site-specific sediment-tissue relationships for the FFS Study Area (as summarized in Attachment 1and described in detail in Appendix A, Data Evaluation Report No. 6). In most cases, it was determined that the functional relationship between COPC and COPEC concentrations in sediment and biological tissue could best be described using regression models. However, Biota Sediment Accumulation Factors (BSAFs) were calculated to estimate Total non-dioxin-like PCBs concentrations in white perch and American eel, and Bioaccumulation Factors (BAFs) were calculated to estimate copper concentrations in white perch, American eel and mummichog based on concentrations of these COPECs in sediment. As explained in Appendix A, correlation of contaminant concentrations in tissue samples with the surface sediment concentrations in the Lower Passaic River was conducted for four representative aquatic species (blue crab, mummichog [a small minnow-like fish], white perch, and American eel). The selection of these species for this analysis was based on the availability of data for them over a wide range of the river (typically RM0 to RM15) and over several periods of study (typically 1999, 2000, 2009 and 2010). These species also form the main basis for estimating exposure point concentrations in biota in the human health and ecological risk assessments for the FFS.

For purposes of developing sediment PRGs, it is assumed that tissue PRGs are based on target fillet tissue concentrations rather than whole fish tissue concentrations for the white perch and American eel. This assumption is consistent with the HHRA, wherein exposure point concentrations for consumption of fish were derived using fillet tissue samples. The regression analyses for the American eel, however, were conducted using whole body samples because the number of fillet samples was not sufficient to develop a robust relationship between sediment and tissue concentrations. Therefore, chemical-specific “fillet multipliers” are applied to the American eel PRG to convert the whole tissue PRGs to fillet tissue concentrations. The fillet multiplier is the ratio of the average fillet tissue concentration to the average whole body tissue concentration, and was derived using the 2009 late summer/early fall data (Appendix A). Similarly, whole body multipliers were applied to the available white perch fillet data to estimate appropriate tissue concentrations for use in developing the ecological PRGs. No multipliers were necessary for blue crab tissue because the tissue type (*e.g.*, muscle + hepatopancreas) evaluated in both the baseline HHRA and BERA is consistent with the dataset used in the regression analyses. Examples of the sediment PRGs derived from white perch, American eel, and blue crab tissue PRGs are provided in Table 1-9. The approach used to estimate sediment PRGs based on whole-body mummichog tissue is similar and differed only in the specific regression model parameters and average lipid content assumed. All regression model parameter values are included in Appendix A.

Table 1-10 provides a summary of sediment PRGs corresponding to fish and blue crab tissue PRGs for each of the number of meals and target risk levels. The sediment PRGs calculated for 56 fish meals are presented as averages of the white perch and American eel sediment PRGs because site-specific data to support consumption patterns is not available; therefore, equal intake of both fish species is assumed and accounted for by providing an average of the individual PRGs. Table 1-11 provides an example calculation for deriving an average sediment PRG for TCDD TEQ based on consuming 56 fish meals consisting of an equally weighted amount of white perch and American eel. Note that sediment PRGs provided under the "12 fish or crab meals per year" is also an average of the sediment PRGs calculated for the white perch, American eel, and blue crab. In the absence of site-specific data to support consumption patterns, equal intake is assumed and accounted for by providing an average of the individual PRGs calculated for the representative species.

2 ECOLOGICAL PRELIMINARY REMEDIATION GOALS

The BERA evaluated risks to wildlife, fish, and benthos associated with direct contact exposures to contaminated sediment in the FFS Study Area and dietary exposures to those chemicals of potential ecological concern (COPECs) capable of bioaccumulating in the estuarine food web. A residue-based analysis was also employed to evaluate the potential hazards associated with tissue burdens measured in fish and estimated in fish and bird eggs. The BERA determined that each COPEC has at least one group of ecological receptors with a HQ above 1. COPECs include:

- Copper
- Lead
- Mercury (including methylmercury)
- Low molecular weight polycyclic aromatic hydrocarbons (LMW PAHs)
- High molecular weight polycyclic aromatic hydrocarbons (HMW PAHs)
- Dieldrin
- Total DDx (as the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT isomers)
- Total non-dioxin-like PCBs (sum of non-dioxin –like-congeners)
- TCDD TEQ (D/F)[7]
- TCDD TEQ (PCBs).

While all of the COPECs evaluated in Appendix D were determined to present unacceptable risks (*i.e.*, HQs greater than 1) to some or all of the receptors evaluated, risk-based PRGs were only developed for dioxins, PCBs, mercury and DDT, because they are the major risk drivers (based on the magnitude of HQs and number of receptors affected) and because there were multiple lines of evidence developed to evaluate how the alternatives would achieve PRGs for these four COPECs after remediation. In addition, most active alternatives (*i.e.*, alternatives other than No Action) designed to address the major risk drivers would also address the other COPECs.

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[7] Consistent with the toxic equivalency approach (Tillitt, 1999), the toxicological basis for the PRGs for D/F and PCB compounds with dioxin-like toxicity is 2,3,7,8-TCDD. TCDD TEQ refers to the combined equivalency associated with all AhR mediated toxicity.

Sediment PRGs were developed for invertebrates (including benthic infauna, such as polychaetes and bivalves, as well as epifaunal groups such as crustaceans), fish and estuarine-dependent wildlife for each measure of effect (ME) for those COPECs determined to be the risk drivers. Table 2-1 summarizes the specific COPECs requiring PRG development for each receptor and ME evaluated in the BERA.

PRGs were calculated following Risk Assessment Guidance for Superfund Part B (USEPA, 1991). Several methodologies were used depending on the receptor category and specific ME. With the exception of benthic invertebrates (sediment benchmark ME), sediment PRG development was a two-step process that involved first calculating a protective tissue concentration in the organism (residue-based MEs) or in the organism's prey (dose-based MEs for wildlife). For each combination of COPEC and receptor category, a sediment PRG was then calculated using site-specific relationships between the COPEC concentration in surficial sediments and biological tissue. These relationships were quantified as either logistic regression or biota-sediment accumulation factor/bioaccumulation factor (BSAF/BAF) models[8] that were developed to support the assessment of future risks based on future modeled sediment and tissue concentrations (Appendix D). Ecological risks were calculated using lower and upper toxicological benchmarks to bound the risk estimates. Sediment PRGs were calculated using the geometric mean of the lower and upper bound benchmark values, which were based on:

- No observed adverse effect levels (NOAELs) and lowest observed adverse effect levels (LOAELs) for wildlife dose-based MEs and residue-based MEs for adult crab and fish
- Lower- and upper-bound sediment benchmark values for benthic macroinvertebrates, or
- Lower confidence levels (LCLs) and upper confidence levels (UCLs) for the residue-based ME for fish embryos.

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[8] Regression models are described in Attachment 1 and model development document in Appendix A, Data Evaluation Report No. 6: "Biota Analysis".

Use of the geometric mean to derive PRGs is consistent with the approach employed in what is known as the "Rule of Five" methodology (USEPA, 2007)[9].

2.1 Calculation of Biota Tissue PRGs

A residue-based analysis was conducted in the BERA to evaluate the significance of measured tissue concentrations of COPECs in fish and blue crabs and estimated tissue concentrations in fish eggs and bird eggs. The toxicity data (*i.e.*, critical body residues [CBRs]) utilized in this assessment were selected as PRGs for fish and crab tissue along with calculated wildlife-protective values. To allow for comparison with other values, CBRs developed to support the evaluation of fish egg and piscivorous bird egg residues were converted to equivalent fish tissue concentrations using biota transfer or biomagnification factors (BMFs). Details regarding the development of CBRs are provided in Appendix D.

Invertebrate Tissue. CBR data for macroinvertebrates were compiled to support the residue-based analysis of blue crab tissue in the BERA; values for the selected COPECs are summarized in Table 2-2. The geometric means of the NOAEL- and LOAEL-based values were selected as PRGs for invertebrate tissue.

Fish Tissue. Table 2-2 also summarizes the CBRs for whole body fish tissue that were compiled to support the residue-based analysis of adult fish tissue in the BERA. The geometric means of the NOAEL- and LOAEL-based values were selected as PRGs for fish tissue.

Fish Tissue Protective of Fish Embryos. Table 2-3 presents adjusted LCL and UCL CBRs compiled to estimate the residue-based risks for fish embryos. The fish egg CBRs were converted into equivalent whole body maternal tissue concentrations by multiplying by a fish/egg BMF for 2,3,7,8-TCDD (*i.e.*, 0.69 as derived by Cook *et al.*, [2003]). The geometric mean of the adjusted NOAEL- and LOAEL-based values was selected as a fish residue value protective of fish embryos that are trans-ovarially exposed to this COPEC.

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[9] The geometric mean is equivalent to the fourth node in a geometric progression consisting of seven elements; the "Rule of Five" methodology allows for derivation of alternative PRGs by selecting different nodal values depending on risk management requirements.

Fish Tissue Protective of Piscivorous Bird Embryos. Table 2-3 presents adjusted NOAEL and LOAEL CBRs compiled to estimate the residue-based risks for bird embryos. To estimate equivalent whole body fish tissue concentrations, the bird egg CBRs were adjusted by multiplying by the prey fish/bird egg BMFs presented in Braune and Nordstrom (1989; *i.e.*, 11.9, 13.3, and 7.0 for Total non-dioxin-like PCBs, Total DDx and 2,3,7,8-TCDD, respectively), assuming that the lipid content in both tissues are equivalent. The geometric means of the adjusted NOAEL- and LOAEL-based values were selected as fish tissue PRGs that would be protective of bird embryos indirectly exposed as a result of a maternal diet that is composed predominantly of fish prey.

Wildlife Diet. Threshold prey tissue concentrations for wildlife exposed to sediment COPECs through consumptive exposure pathways (*i.e.,* prey ingestion) were calculated using the same exposure dose equations used to quantify risks to representative wildlife receptors in the BERA. The modeled representative receptors, the mink (*Neovison vison*) and Great blue heron (*Ardea herodias*), were selected due to their relatively large dietary exposures to sediment-associated chemicals that can bioaccumulate in biological tissue. Equation 3 was used to estimate PRGs for piscivorous wildlife receptors in the FFS Study Area.

$$C_{biota} = \frac{THQ * TRV * BW}{\left(IR_{biota} * P_{biota} * SFF * ED\right)} \qquad \text{Equation 3}$$

where:

C_{biota}: PRG for prey tissue protective of bioaccumulation hazards associated with the fish consumption pathway (mg COPEC/kg biota).

THQ: Target HQ for the COPEC based on tissue residue effects (dimensionless).

TRV: Toxicity reference value: receptor-specific literature-based toxicity threshold value (mg/kg-d).

BW: Receptor body weight (kg).

IR_{biota}: Daily biota ingestion rate (kg biota consumed per day).

P_{biota}: Percentage of biota in the diet.

SFF: Site foraging factor (%); fraction of time receptor is assumed to forage at the site.

ED: Exposure duration (unitless); fraction of year individuals are present in the vicinity of the site.

Table 2-4 summarizes the TRVs and exposure parameters used in the development of prey tissue concentrations (C_{biota}) that are protective of wildlife. Similar to other derivations, the selected PRGs based on wildlife prey tissue concentrations presented in Table 2-4 are the geometric means of the NOAEL- and LOAEL-based values.

Summary of Biota PRGs. Table 2-5 summarizes the biota tissue PRGs derived for protection of invertebrates, fish, and birds (residue-based PRGs) and aquatic-feeding wildlife (dose-based PRGs). The values represent the geometric mean of the lower- and upper-bound tissue concentrations (in mg COPEC/kg wet weight tissue) that are considered protective of the specific MEs for which they are based. As summarized in the right-hand section of the table, for each COPEC, the lowest geometric mean value for multiple endpoints for a given ecological receptor category (*e.g.*, fish and wildlife) is selected as the PRG. For example, in the case of fish, the tissue PRGs based on adult fish CBRs were the selected basis for the overall fish tissue PRGs, as TCDD TEQ is the only COPEC with multiple values and the CBR protective of effects in fish embryos is higher (*i.e.*, 0.000036 versus 0.0000013 mg/kg wet weight [ww] tissue) than the corresponding CBR for adult fish. There is little overlap in the COPECs identified for avian and mammalian wildlife; in side by side comparisons, the mammal-based values are lower than the corresponding avian-based values for mercury (0.069 and 0.18 ww tissue) and TCDD TEQ (0.0000014 and 0.000086 ww tissue, respectively). The tissue residue-based PRGs for invertebrates are the lowest values (*i.e.*, most protective) overall for all COPECs with the exception of TCDD TEQ, for which the fish is the most sensitive receptor category.

2.2 Calculation of Sediment PRGs Based on Biota Tissue PRGs

The sediment concentrations of individual COPECs expected to result in biota tissue concentrations equivalent to tissue PRGs were estimated primarily[10] using regression models or uptake factors developed for organics and metals for invertebrates and fish found throughout the

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[10] BSAFs were used in lieu of regression models to estimate the sediment PRGs for Total non-dioxin-like PCBs (American eel and white perch).

Lower Passaic River below the Dundee Dam (as summarized in Attachment 1). The sediment PRGs protective of ecological effects associated with tissue residues were also compared to the sediment screening benchmarks used in the BERA.

Sediment Screening Benchmarks. Table 2-6 summarizes the lower- and upper-bound sediment benchmarks along with geometric mean values. In the case of benthic invertebrates, risks for all COPECs except 2,3,7,8-TCDD were estimated by comparing sediment concentrations to screening benchmarks derived using either logistic regression models (USEPA, 2005) relating sediment exposure to 10-day survival effects in amphipods or National Oceanic and Atmospheric Administration (NOAA) effects range – low values (ER-Ls) for estuarine habitat (Long *et al*., 1995). For 2,3,7,8-TCDD, Kubiak *et al*. (2007) derived a site-specific sediment PRG for bivalves based on a reproductive effects study by Wintermyer and Cooper (2003) that identified significant adverse effects on gonadal and embryonic development associated with the bioaccumulation of 2,3,7,8-TCDD in transplanted oysters in Newark Bay and the Arthur Kill compared to Sandy Hook. A functional relationship between tissue burden and sediment exposures was determined using co-located suspended solids chemistry data from the Contamination Assessment and Reduction Project (CARP). The oyster-derived value (Kubiak *et al*., 2007) is appropriate for characterizing ecological risks and developing ecologically-protective PRGs because (1) it is based on site-specific field and laboratory work and (2) it is important to achieve sediment concentrations that will allow the restoration of historically rich oyster beds (Kurlansky, 2006) in areas downstream of the Passaic River, including Newark Bay. As attested to by observations of numerous living oysters along the western shore of Newark Bay and off Kearney Point during recent surveys, Newark Bay currently meets the physical and habitat conditions required for oyster survival, and living oysters were collected in the Lower Passaic River during the CPG biological sampling program (Windward Environmental, 2012). Finally, the oyster-based PRG for 2,3,7,8-TCDD will protect other less sensitive organisms, which is also beneficial to the ecosystem.

Table 2-7 summarizes the ecologically-protective sediment PRGs that were calculated for each of the representative receptors and endpoints evaluated in the BERA. In addition to the sediment benchmark-based PRGs (Table 2-6), which are expressed as sediment concentrations, the biota tissue PRGs summarized in Table 2-5 were converted to equivalent sediment concentrations using the sediment-tissue relationships described in DER No. 6 and summarized in Attachment 1. Residue-based sediment PRGs were derived for the blue crab tissue PRGs and the lowest (*i.e.*, based on the specific white perch, American eel and mummichog models) of the fish tissue PRGs protective of residue effects in adult fish and of reproductive effects in piscivorous birds (*i.e.*, Columns 3 – 5 in Table 2-7). The species for which the lowest sediment PRG was calculated varied depending on the specific COPEC and model as follows: white perch (Total non-dioxin-like PCBs, Total DDx and TCDD TEQ) and American eel (mercury).

Wildlife dose-based sediment PRGs were derived based on prey tissue concentrations protective of consumption exposures for both heron and mink receptors as summarized in Table 2-5. The specific model and diet that resulted in the lowest sediment PRG varied depending on the specific COPEC such that Total non-dioxin-like PCBs, Total DDx and TCDD TEQ had the lowest sediment PRGs for a white perch diet and mercury had the lowest sediment PRG for an American eel diet.

The right-hand section of Table 2-7 summarizes the overall basis for the ecologically-protective sediment PRGs, and the specific ecological receptor categories associated with the lowest overall sediment PRGs are bolded. In the case of macroinvertebrates, the CBR-based PRG for total non-dioxin-like PCBs and the site-derived oyster tissue-based CBR for 2,3,7,8-TCDD are the basis for the overall ecological sediment PRGs. Wildlife-derived values for mercury and Total DDx are the most protective and the sediment PRG for TCDD TEQ (0.0000011 mg/kg or 1.1 pg/kg) is the same for both fish and wildlife and approximately 3-fold less than the sediment PRG for 2,3,7,8-TCDD (*i.e.*, 0.0000032 mg/kg) based on the site-specific oyster reproduction study.

3 IDENTIFICATION OF BACKGROUND CONCENTRATIONS

Background contaminant contributions to the FFS Study Area were considered to adequately understand contaminant sources and establish realistic risk reduction goals. Newark Bay, the Upper Passaic River (located above Dundee Dam) and New York/New Jersey Harbor were considered as potential background locations. USEPA guidance (USEPA, 2002) defines "background" as constituents and locations that are not influenced by releases from the site and includes both anthropogenic and naturally derived constituents. Tidal exchange between the Lower Passaic River (which includes the FFS Study Area) and Newark Bay results in net transport of contaminants from the Lower Passaic River (and the FFS Study Area) to Newark Bay. Therefore, Newark Bay is influenced by releases from the FFS Study Area. The dam physically isolates the proximal Dundee Lake and other Upper Passaic River sediments from Lower Passaic River influences. Due to the proximity of Upper Passaic River sediments to the FFS Study Area and the demonstrated geochemical connection to a portion of the Lower Passaic River sediment contamination, Upper Passaic River sediments were chosen as representative of "background" for the FFS Study Area. Table 3-1 lists the concentrations of COPCs and COPECs detected in recently-deposited surficial sediments, as represented by four cores, two sediment traps, and four sediment grab samples collected from the Upper Passaic River immediately above (and below for sediment traps) Dundee Dam (refer to Chapters 2 and 4 of the RI Report for more details).

Estimates of cancer risks and noncancer health hazards associated with background sediment concentrations for consumption of fish and crabs were calculated for Total non-dioxin-like PCBs, 2,3,7,8-TCDD, and mercury and are presented in Section 3.1. Similarly, estimates of ecological risk associated with background sediment concentrations were calculated for copper, lead, mercury, HMW PAHs, dieldrin, Total DDx, Total non-dioxin-like PCBs, and TCDD TEQs and are presented in Section 3.2.

3.1 Human Health Evaluation of Background Concentrations

Estimates of cancer risk and noncancer health hazard associated with background sediment concentrations for consumption of fish and crabs were calculated for Total non-dioxin-like PCBs, 2,3,7,8-TCDD (representing TCDD TEQ (D/F), and mercury (representing methylmercury) using the same risk assessment methods and assumptions that were used in the baseline HHRA for the adult angler/sportsman and child who consumes the adult's catch. Estimates of cancer risk and noncancer health hazard associated with background concentrations were only calculated for those COPCs with individual cancer risks above 1×10^{-4} and individual noncancer HIs above 1. Fish and crab tissue concentrations were estimated from background sediment concentrations using the same regression models developed for the FFS Study Area as summarized in Attachment 1 and described in detail in Appendix A, Data Evaluation Report No. 6. Table 3-2 summarizes the estimates of cancer risk and noncancer health hazards for ingestion of fish and crab associated with background concentrations.

In background sediment concentrations, for dioxins, all of the estimated cancer risks are within the target cancer risk range of 1×10^{-4} to 1×10^{-6} specified in the NCP, and the HQs are less than the THQ of 1. For Total non-dioxin-like PCBs, estimated cancer risks are within the target cancer risk range of 10^{-4} to 10^{-6} specified in the NCP except for the adult (ingestion of fish), and all of the HQs are greater than the THQ of 1. For methylmercury, HQs are equal to or greater than the THQ of 1 for ingestion of fish, but less than the HI of 1 for ingestion of crab.

3.2 Ecological Evaluation of Background Concentrations

Hazard estimates associated with ecological exposures to background sediment concentrations were calculated for each COPEC[11] for which background concentrations have been established (Table 3-1) using a similar risk assessment approach and set of assumptions as used in the assessment of baseline risks. Background COPEC concentrations in whole body fish and crab tissues were estimated using the sediment tissue functional relationships presented in Appendix A for white perch, American eel, mummichog and blue crab (Table 3-3) and Table 1-9 presents

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[11] Upgradient analytical chemistry data are not available for PCBs congeners or dioxin and furan congeners, excepting 2,3,7,8-TCDD. In the case of fish and wildlife receptors, the TCDD TEQ (D/F) COPEC was estimated using the 2,3,7,8-TCDD data.

some sample tissue calculations. Table 3-4 summarizes the hazard estimates based on comparison of background sediment concentrations to sediment benchmarks and comparison of estimated crab and fish concentrations (*i.e.*, whole body tissue residues) to CBRs.

With the exception of the TCDD TEQ concentrations (both PCBs and D/F), which could not be quantified because analytical chemistry data for congeners in background sediments are not available, the background sediment concentrations of all COPECs were determined to result in hazard estimates greater than or equal to 1 for one or more receptors. Background concentrations of LMW PAHs, HMW PAHs, Total non-dioxin-like PCBs and Total DDx exceed the lower-bound sediment benchmarks by greater than an order of magnitude; background concentrations for inorganic COPECs and dieldrin also exceed one or both of their respective benchmarks (Table 3-4). However, the background 2,3,7,8-TCDD concentration does not exceed the site-specific sediment benchmark. The total HI for the lower-bound sediment benchmark endpoint is 100, with the PAH and pesticide COPECs contributing approximately 60 percent to the overall hazard estimate. Both NOAEL- and LOAEL-based HIs for the blue crab CBR endpoint also exceed 1 (40 and 10, respectively). Background concentrations of Total non-dioxin-like PCBs contribute approximately 75-80% to the total hazard estimates, and both NOAEL- and LOAEL-based HQs exceed 1 (*i.e.*, 30 and 8, respectively). In addition, the NOAEL-based, but not LOAEL-based, HQs for copper, mercury, HMW PAHs, dieldrin and 2,3,7,8-TCDD are 1 or greater, ranging to 3 (dieldrin), whereas background sediment concentrations of lead, LMW PAHs and Total DDx do not appear to pose a bioaccumulation hazard to this receptor (Table 3-4).

A number of NOAEL- and LOAEL-based HQs for the generic fish category (HIs of 30 and 7, respectively) and mummichog (HIs of 9 and 2, respectively) equal or exceed 1 for the background conditions. In the case of the generic fish category, HQs for copper and Total non-dioxin-like PCBs are the largest and are the only two COPECs with LOAEL-based HQs equal to or exceeding 1; NOAEL-based HQs also equal or exceed 1 for mercury (HQ=3), dieldrin (HQ=4), Total DDx (HQ=4) and TCDD TEQ (HQ=2) (Table 3-4). Background conditions appear to pose somewhat less of a bioaccumulation hazard to forage fish (as represented by the mummichog); only the NOAEL-based HQs for copper (HQ=4) exceeds 1.

Table 3-5 summarizes the hazard estimates for mink and heron receptors based the incidental ingestion of (background) sediment and consumption of prey that have bioaccumulated COPECs at background levels in their tissues. NOAEL- and LOAEL-based HIs for the heron are 10 and 3, respectively, based on the generic fish diet and 10 and 2, respectively, based on a mummichog diet. Only the NOAEL-based HQs for lead, HMW PAHs and Total DDx (generic fish scenario only) exceed 1 (HQs=46 and 3, respectively). As no LOAEL-based HQ exceeds 1, there is considerable uncertainty regarding the potential impact of background exposures to the health of exposed water-dependent avifauna because the actual effects concentration rests somewhere between the NOAEL and LOAEL. There is low potential for ecological consequences to mink exposed to background conditions. The NOAEL- and LOAEL-based HIs are 10 and 6, respectively, and NOAEL-based HQs only exceed 1 in the case of mercury (HQ=3), Total non-dioxin-like PCBs (HQ=4) and TCDD TEQ (HQ=5). Mercury and Total non-dioxin-like PCBs appear to pose the greatest hazard to mink, as the LOAEL-based HQs for these COPECs also exceed 1.

USEPA guidance entitled “Role of Background in the CERCLA Cleanup Program” (USEPA, 2002) provides that a comparison of background and site concentrations may help EPA risk managers make decisions concerning remedial actions. Similarly, the Contaminated Sediment Guidance states that project managers should consider background contributions to sites to adequately understand contaminant sources and establish realistic risk reduction goals. However, modeling predicts that post-remediation, the suspended sediment entering the FFS Study Area would mix with other sources into the FFS Study Area (mainly the tidal exchange with Newark Bay) and with the cleaner solids in the water column resulting from a remediated FFS Study Area. In addition, suspended sediments depositing in the FFS Study Area would mix with the clean material on the river bed after remediation. The result of this mixing within the water column and settling, remobilization and redeposition would be surface sediment concentrations of COCs that are lower than the background concentrations above the Dam.

4 ACRONYMS

2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
AhR	Aryl Hydrocarbon Receptor
AT	Averaging Time
ATSDR	Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation Factor
BASF	biota-sediment accumulation factor
BERA	Baseline Ecological Risk Assessment
BMF	Biomagnification Factor
BW	Body Weight of Receptor
CalEPA	California Environmental Protection Agency
CARP	Contamination Assessment and Reduction Project
C_{biota}	Chemical Concentration in Biota
CBR	Critical Body Residue
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Conversion Factor
C_f	Crab or Fish Tissue Concentration
C_F	Lipid-normalized Crab or Fish Fillet Tissue Concentration
COPC	Chemical of Potential Concern
COPEC	Chemical of Potential Ecological Concern
C_s	Sediment Concentration
CSF	Oral Cancer Slope Factor
CTE	Central Tendency Exposure
C_W	Lipid-normalized Crab or Fish Whole Body Tissue Concentration
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
D/F	Dioxin/Furan
DDT	Dichlorodiphenyltrichloroethane
ED	Exposure Duration

EF	Exposure Frequency
ER-L	Effects Range-Low
FI	Fraction from Source
FFS	Focused Feasibility Study
f_{iron}	Fraction Iron Content in Surficial Sediment
f_L	Fraction Lipid Content in Tissue
f_{lipid}	Fraction Lipid Content in Tissue
f_{OC}	Fraction Organic Carbon Content in Surficial Sediment
g	gram
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMW PAH	High Molecular Weight PAH
HQ	Hazard Quotient
IR_{biota}	Biota Ingestion Rate
IR	Ingestion Rate
IRIS	Integrated Risk Information System
kg	kilogram
LCL	Lower Confidence Level
LOAEL	Lowest Observed Adverse Effects Level
LMW PAH	Low Molecular Weight PAH
ME	Measure of Effect
mg	milligram
MRL	Minimal Risk Level
NA	Not Available or Not Applicable
NCP	National Contingency Plan
ND	Not Determined
ng	nanogram
NJDEP	New Jersey Department of Environmental Protection
NJDHSS	New Jersey Department of Health and Senior Services
NOAA	National Oceanic and Atmospheric Administration

NOAEL	No Observed Adverse Effects Level
OEHHA	Office of Environmental Health Hazard Assessment
OSWER	Office of Solid Waste and Emergency Response,
P_{biota}	Percentage of Biota in the Diet
PAR	Pathways Analysis Report
PCB	Polychlorinated Biphenyl
ppb	Parts Per Billion
ppm	Parts Per Million
ppt	Part Per Trillion
PPRTV	Provisional Peer-Reviewed Toxicity Values
PRG	Preliminary Remediation Goal
RfD	Reference Dose
RME	Reasonably Maximum Exposure
SFF	Site Foraging Frequency
TCDD	Tetrachlorodibenzo-*p*-dioxin
TEQ	Toxic Equivalency Quotient
THQ	Target Hazard Quotient
TOC	Total Organic Carbon
Total DDx	Sum of DDD, DDE, and DDT Isomers
TR	Target Risk
TRV	Toxicity Reference Value
µg	microgram
UCL	Upper Confidence Level
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
ww	wet weight

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TABLES

Table 1-1 Summary of Baseline Current Cancer Risk for Ingestion of Fish and Crab

Fish Cancer Risk(a) - RME					
COPC	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk(b)
TCDD TEQ (D/F)	3.E-03	1.E-03	1.E-03	4.E-03	70%
TCDD TEQ (PCBs)	4.E-04	2.E-04	2.E-04	6.E-04	11%
Total non-dioxin-like PCBs	6.E-04	3.E-04	2.E-04	8.E-04	16%
4,4'-DDD	3.E-06	1.E-06	1.E-06	4.E-06	0.08%
4,4'-DDE	7.E-06	3.E-06	3.E-06	1.E-05	0.21%
4,4'-DDT	3.E-07	1.E-07	1.E-07	4.E-07	0.01%
Total Chlordane	4.E-06	2.E-06	1.E-06	5.E-06	0.10%
Dieldrin	7.E-05	3.E-05	3.E-05	9.E-05	2%
Methylmercury	ND	ND	ND	ND	NA
Total	4.E-03	2.E-03	1.E-03	5.E-03	--
Crab Cancer Risk(a) - RME					
COPC	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk(b)
TCDD TEQ (D/F)	1.E-03	5.E-04	4.E-04	2.E-03	82%
TCDD TEQ (PCBs)	2.E-04	8.E-05	7.E-05	2.E-04	12%
Total non-dioxin-like PCBs	8.E-05	3.E-05	3.E-05	1.E-04	5%
4,4'-DDD	5.E-07	2.E-07	2.E-07	8.E-07	0.04%
4,4'-DDE	2.E-06	9.E-07	8.E-07	3.E-06	0.14%
4,4'-DDT	1.E-07	5.E-08	5.E-08	2.E-07	0.01%
Total Chlordane	2.E-07	9.E-08	8.E-08	3.E-07	0.01%
Dieldrin	1.E-05	6.E-06	5.E-06	2.E-05	1%
Methylmercury	ND	ND	ND	ND	NA
Total	1.E-03	6.E-04	5.E-04	2.E-03	--

Note: Scientific notation such as 1.E-03 is equivalent to 1×10^{-3}.

NA – not applicable.

ND – not determined.

(a) Cancer risk is expressed as one significant figure.

(b) Percent contribution to total risk is based on the summed risk of the adult and child receptors.

Table 1-2 Summary of Baseline Current Noncancer Health Hazards for Ingestion of Fish and Crab

Fish Noncancer Health Hazard Quotients - RME				
COPC	Adult	Adolescent	Child	Percent Contribution to Total HI[(a)]
TCDD TEQ (D/F)	71	63	110	56%
TCDD TEQ (PCBs)	11	10	18	9%
Total non-dioxin-like PCBs	42	38	65	33%
4,4'-DDD	ND	ND	ND	ND
4,4'-DDE	ND	ND	ND	ND
4,4'-DDT	0.004	0.004	0.007	0.004%
Total Chlordane	0.06	0.06	0.1	0.05%
Dieldrin	0.2	0.2	0.4	0.2%
Methylmercury	2	2	3	1%
Total HI	126	113	195	--
Crab Noncancer Health Hazard Quotients - RME				
COPC	Adult	Adolescent	Child	Percent Contribution to Total HI[(a)]
TCDD TEQ (D/F)	32	29	50	75%
TCDD TEQ (PCBs)	5	4	7	11%
Total non-dioxin-like PCBs	6	5	9	13%
4,4'-DDD	ND	ND	ND	ND
4,4'-DDE	ND	ND	ND	ND
4,4'-DDT	0.002	0.002	0.003	0.005%
Total Chlordane	0.003	0.003	0.005	0.01%
Dieldrin	0.05	0.04	0.1	0.1%
Methylmercury	0.5	0.5	0.8	1%
Total HI	43	38	67	--

HI – hazard index.
NA –not applicable.
ND – not determined.
(a) Percent contribution is presented for the child.

Table 1-3 Summary of Baseline Future Modeled Cancer Risk for Ingestion of Fish and Crab

Fish Cancer Risk$^{(a)}$ - RME					
COPC	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk$^{(b)}$
TCDD TEQ (D/F)	1.E-03	6.E-04	6.E-04	2.E-03	50%
TCDD TEQ (PCBs)	1.E-03	5.E-04	4.E-04	1.E-03	37%
Total non-dioxin-like PCBs	3.E-04	2.E-04	2.E-04	5.E-04	13%
4,4'-DDD	4.E-06	2.E-06	2.E-06	6.E-06	0.1%
4,4'-DDE	6.E-06	3.E-06	3.E-06	9.E-06	0.2%
4,4'-DDT	6.E-06	3.E-06	2.E-06	8.E-06	0.2%
Total Chlordane	2.E-06	1.E-06	1.E-06	3.E-06	0.1%
Methylmercury	ND	ND	ND	ND	NA
Total	3.E-03	1.E-03	1.E-03	4.E-03	
Crab Cancer Risk$^{(a)}$ - RME					
COPC	Adult	Adolescent	Child	Adult + Child	Percent Contribution to Total Risk$^{(b)}$
TCDD TEQ (D/F)	6.E-04	3.E-04	3.E-04	9.E-04	45%
TCDD TEQ (PCBs)	7.E-04	3.E-04	3.E-04	9.E-04	49%
Total non-dioxin-like PCBs	7.E-05	4.E-05	3.E-05	1.E-04	6%
4,4'-DDD	4.E-07	2.E-07	2.E-07	6.E-07	0.03%
4,4'-DDE	7.E-07	3.E-07	3.E-07	1.E-06	0.1%
4,4'-DDT	6.E-07	3.E-07	3.E-07	8.E-07	0.04%
Total Chlordane	2.E-07	7.E-08	6.E-08	2.E-07	0.01%
Methylmercury	ND	ND	ND	ND	NA
Total	1.E-03	6.E-04	6.E-04	2.E-03	

Note: Scientific notation such as 1.E-03 is equivalent to 1×10^{-3}.
NA – not applicable.
ND – not determined.
(a) Cancer risk is expressed as one significant figure.
(b) Percent contribution to total risk is based on the summed risk of the adult and child receptors.

Table 1-4 Summary of Baseline Future Modeled Noncancer Health Hazards for Ingestion of Fish and Crab

Fish Noncancer Health Hazard Quotients- RME				
COPC	Adult	Adolescent	Child	Percent Contribution to Total HI[(a)]
TCDD TEQ (D/F)	38	34	65	40%
TCDD TEQ (PCBs)	27	27	50	30%
Total non-dioxin-like PCBs	24	24	45	28%
4,4'-DDD	ND	ND	ND	NA
4,4'-DDE	ND	ND	ND	NA
4,4'-DDT	0.1	0.09	0.2	0.1%
Total Chlordane	0.04	0.04	0.06	0.04%
Methylmercury	1	1	2	2%
Total HI	90	87	163	
Crab Noncancer Health Hazard Quotients - RME				
COPC	Adult	Adolescent	Child	Percent Contribution to Total HI[(a)]
TCDD TEQ (D/F)	17	16	29	41%
TCDD TEQ (PCBs)	18	17	32	45%
Total non-dioxin-like PCBs	5	5	10	14%
4,4'-DDD	ND	ND	ND	NA
4,4'-DDE	ND	ND	ND	NA
4,4'-DDT	0.01	0.01	0.02	0.02%
Total Chlordane	0.003	0.002	0.004	0.01%
Methylmercury	0.3	0.3	0.5	1%
Total HI	40	39	71	

HI – hazard index.
NA – not applicable.
ND – not determined.
(a) Percent contribution is presented for the child.

Table 1-5 Summary of Exposure Parameters for Calculation of Fish/Crab Tissue PRGs

Exposure Parameter	Definition	Units	Value
C_{biota}	Chemical Concentration in Biota Tissue (*i.e.*, fish or crab)	mg/kg	Chemical-specific
TR	Target Risk	unitless	1×10^{-6} 1×10^{-5} 1×10^{-4}
THQ	Target Hazard Quotient	unitless	1.0
IR	Ingestion Rate	grams/meal	227 (8 ounces)(a)
EF	Exposure Frequency	fish meals/year(b)	56
		crab meals/year(c)	34
ED	Exposure Duration	years	24
BW	Body Weight	kg	70
AT	Averaging Time	days	25,550 for carcinogenic effects; 8,760 (ED x 365 days) for non-carcinogenic effects
FI	Fraction from Source	unitless	1.0
CF	Conversion Factor	kg/g	0.001
CSF	Oral Cancer Slope Factor	$(mg/kg\text{-}day)^{-1}$	Chemical-specific(d)
RfD	Oral Reference Dose	mg/kg-day	Chemical-specific(d)

mg/kg - milligrams per kilogram.

mg/kg-day – milligram per kilogram per day.

$(mg/kg\text{-}day)^{-1}$ – per milligram per kilogram per day.

kg/g – kilogram per gram.

(a) Source: New Jersey Department of Environmental Protection (NJDEP), 2010; USEPA, 2011; and USEPA, 2000.

(b) 56 meals/year = ~1 fish meal every 1 week consistent with the ingestion rate used in the HHRA as determined in USEPA (2012). (for alternate number of meals discussed in Section 1.2, the following EFs are considered: 12 meals/year = 1 fish meal every month; 6 meals/year = 1 fish meal every other month; 2 meals/year = 1 fish meal every six months; 1 fish meal/year).

(c) 34 meals/year = ~1 crab meal every 1.5 weeks consistent with the ingestion rate used in the HHRA, as determined in USEPA (2012) (for alternate number of meals discussed in Section 1.2, the following EFs are considered: 12 meals/year = 1 crab meal every month; 6 meals/year = 1 crab meal every other month; 2 meals/year = 1 crab meal every six months; 1 crab meal/year).

(d) Refer to Table 1-6.

Table 1-6 Oral Toxicity Values for Calculation of Fish/Crab Tissue PRGs

COPC	Oral Toxicity Values	
	Cancer Slope Factor	Reference Dose
	$(mg/kg\text{-}day)^{-1}$	mg/kg-day
TCDD TEQ	1.50×10^{5} (a)	7.0×10^{-10}
Total non-dioxin-like PCBs	2.00×10^{0}	2.0×10^{-5} (b)
Methylmercury	NA(c)	1.0×10^{-4}

mg/kg-day – milligram per kilogram per day.

NA - Not Available

(a) Cancer slope factor obtained from HEAST (USEPA, 1997).

(b) Oral reference dose for Total non-dioxin-like PCBs is based on the oral reference dose for Aroclor 1254.

(c) Classification — C; possible human carcinogen, but an oral cancer slope factor has not been developed for this chemical.

Table 1-7 Summary of the Tissue PRGs Developed for Consumption of Fish and Crab

PRGs	COPCs	Cancer Risk-Based PRGs (ng/g)			Noncancer Hazard-Based PRGs (ng/g)
		1×10^{-6}	1×10^{-5}	1×10^{-4}	
Consumption of Fish by an Adult Angler(a)	TCDD TEQ	0.000039	0.00039	0.0039	0.0014
	Total non-dioxin-like PCBs	2.9	29	290	40
	Methylmercury	ND(c)			200
Consumption of Crab by an Adult Angler(b)	TCDD TEQ	0.000064	0.00064	0.0064	0.0023
	Total non-dioxin-like PCBs	4.8	48	480	66
	Methylmercury	ND(c)			330

Concentrations are presented as two significant figures.

ng/g - nanograms per gram (equivalent to parts per billion [ppb])

ND - Not Determined.

(a) Assumes 56 eight-ounce fish meals per year consistent with the ingestion rate used in the HHRA (Appendix D).

(b) Assumes 34 eight-ounce crab meals per year consistent with the ingestion rate used in the HHRA (Appendix D).

(c) Classification —There is no quantitative estimate of carcinogenic risk from oral exposure.

Table 1-8 Summary of Risk-Based Tissue Levels Based on the Number of Fish or Crab Meals per Year for the Adult Angler Receptor

	Cancer Risk-Based Tissue Concentrations Based on Number of Fish and Crab Meals[(a)] per Year for an Adult (ng/g)								
	56 fish meals per year			34 crab meals per year			12 fish or crab meals per year		
COPC	1×10^{-6}	1×10^{-5}	1×10^{-4}	1×10^{-6}	1×10^{-5}	1×10^{-4}	1×10^{-6}	1×10^{-5}	1×10^{-4}
TCDD TEQ[(b)]	0.000039	0.00039	0.0039	0.000064	0.00064	0.0064	0.00018	0.0018	0.018 ▨
Total non-dioxin-like PCBs[(b)]	2.9	29	290 ▨	4.8	48	480 ▨	14	140	1,400 ▨
Methylmercury	Classification — C; possible human carcinogen; There is no quantitative estimate of carcinogenic risk from oral exposure.								

	Noncancer Hazard-Based Tissue Concentrations Based on Number of Fish or Crab Meals[(a)] per Year for an Adult (ng/g)		
COPC	56 fish meals per year	34 crab meals per year	12 fish or crab meals per year
TCDD TEQ[(b)]	0.0014	0.0023	0.0066
Total non-dioxin-like PCBs[(b)]	40	66	190
Methylmercury	200	330	940 ▨

Concentrations are presented as two significant figures.

ng/g - nanogram per gram (or parts per billion [ppb]).

▨ - Indicates that the risk-based value exceeds the NJDEP advisory trigger level and would not be protective or allow additional consumption of fish/crabs. The NJDEP uses 'do not eat' values of 0.0077 ng/g, 240 ng/g, and 540 ng/g to set fish consumption advisories for TCDD TEQ, PCBs, and mercury, respectively. Use of PRGs that exceed these NJDEP advisory triggers would not be protective or allow additional consumption of fish/crabs.

(a) For fish, 56 meals/year = ~1 fish meal every week (consistent with the HHRA ingestion rate [Appendix D]); For crab, 34 meals/year = ~1.5 crab meal every week (consistent with the HHRA ingestion rate [Appendix D]); 12 meals/year = 1 fish or crab meal every month.

(b) For Total non-dioxin-like PCBs and TCDD TEQ, PRGs have been calculated for both carcinogenic and non-carcinogenic health effects. It is recommended that the toxicological effect resulting in the more conservative PRG be used to be protective of both types of health effects.

Table 1-9 Example Calculation for Estimating Sediment PRGs(a)

Target Level	Tissue	Equation Number(b)	PRG_{tissue}(c)	f_{OC}	f_L	f_{iron}	β_0(d)	β_1(d)	β_2(d)	BSAF	Fillet Multiplier(e)	$PRG_{sediment}$
TCDD TEQ (ng/kg or ppt)												
1 x 10^{-6}	White Perch	1	0.039	0.047	0.050	NA	-0.0039	0.9537	1.3431	NA	NA	0.11
	American Eel	1	0.065	0.047	0.067	NA	0.0916	0.6344	1.1817	NA	0.60	0.08
	Blue Crab	1	0.064	0.047	0.015	NA	-2.5412	0.9379	0.5459	NA	NA	0.43
1 x 10^{-5}	White Perch	1	0.39	0.047	0.050	NA	-0.0039	0.9537	1.3431	NA	NA	1.2
	American Eel	1	0.65	0.047	0.067	NA	0.0916	0.6344	1.1817	NA	0.60	3.1
	Blue Crab	1	0.64	0.047	0.015	NA	-2.5412	0.9379	0.5459	NA	NA	5.0
1 x 10^{-4}	White Perch	1	3.9	0.047	0.050	NA	-0.0039	0.9537	1.3431	NA	NA	13
	American Eel	1	6.5	0.047	0.067	NA	0.0916	0.6344	1.1817	NA	0.60	117
	Blue Crab	1	6.4	0.047	0.015	NA	-2.5412	0.9379	0.5459	NA	NA	58
HQ = 1	White Perch	1	1.4	0.047	0.050	NA	-0.0039	0.9537	1.3431	NA	NA	5
	American Eel	1	2.3	0.047	0.067	NA	0.0916	0.6344	1.1817	NA	0.60	24
	Blue Crab	1	2.3	0.047	0.015	NA	-2.5412	0.9379	0.5459	NA	NA	19
Total non-dioxin-like PCBs (µg/kg or ppb)												
1 x 10^{-6}	White Perch	2	2.9	0.047	0.050	NA	NA	NA	NA	0.9176	NA	3.0
	American Eel	2	4.8	0.047	0.067	NA	NA	NA	NA	0.9914	0.60	3.4
	Blue Crab	1	4.8	0.047	0.015	NA	2.2930	0.6635	0.7314	NA	NA	1.6
1 x 10^{-5}	White Perch	2	29	0.047	0.050	NA	NA	NA	NA	0.9176	NA	30
	American Eel	2	48	0.047	0.067	NA	NA	NA	NA	0.9914	0.60	34
	Blue Crab	1	48	0.047	0.015	NA	2.2930	0.6635	0.7314	NA	NA	51
1 x 10^{-4}	White Perch	2	290	0.047	0.050	NA	NA	NA	NA	0.9176	NA	295
	American Eel	2	480	0.047	0.067	NA	NA	NA	NA	0.9914	0.60	337
	Blue Crab	1	483	0.047	0.015	NA	2.2930	0.6635	0.7314	NA	NA	1628
HQ = 1	White Perch	2	40	0.047	0.050	NA	NA	NA	NA	0.9176	NA	41
	American Eel	2	66	0.047	0.067	NA	NA	NA	NA	0.9914	0.60	47
	Blue Crab	1	66	0.047	0.015	NA	2.2930	0.6635	0.7314	NA	NA	82
Methylmercury (mg/kg or ppm)												
HQ = 1	White Perch	3	0.201	NA	NA	0.025	-2.8387	0.3747	NA	NA	NA	0.67
	American Eel	3	0.14	NA	NA	0.025	-3.0790	0.3747	NA	NA	1.48	0.45
	Blue Crab	3	0.33	NA	NA	0.025	-3.9115	0.3747	NA	NA	NA	45

(a) The statistical analytical results used to develop sediment PRGs are summarized in Attachment 1 of this Appendix and detailed in the Data Evaluation Report No. 6: "Biota Analysis" (LBG, 2013). Note that the regression model derived for mercury was based on analytical tissue data for elemental mercury due to a lack of methylmercury analytical results in the historical tissue dataset. As such, the data for elemental mercury and methyl mercury were assumed to be equivalent and treated as if all were methyl mercury.

(b) Indicates the regression equation used to determine $PRG_{sediment,}$ (refer to Attachment 1 of this Appendix for model description)

(c) PRG_{tissue} obtained from Table 1-8 with unit conversions where necessary.

(d) β terms represent exponents on the various factors (*i.e.*, regression coefficients).

(e) PRG_{tissue} is divided by the fillet multiplier for the American eel.

ng/kg – nanogram per kilogram, or parts per trillion (ppt).
ng/g – nanogram per gram, or parts per billion (ppb).
mg/kg – milligram per kilogram or parts per million (ppm).
BSAF - biota sediment accumulation factor.
NA – not applicable.
HQ- hazard quotient.

f_{OC} – fraction of total organic carbon in the sediment in g organic carbon/ g sediment.
f_L – fraction of lipid in the animal (unitless).
$PRG_{sediment}$ – concentration in sediment.
f_{iron} – iron concentration in the sediment in g iron / g sediment.

Equation 1: $PRG_{sediment} = e\wedge\left[\frac{ln(PRG_{tissue})-\beta_0-\beta_2 * ln(f_L)}{\beta_1}\right] * f_{OC}$

Equation 2: $PRG_{sediment} = \frac{PRG_{tissue} * f_{OC}}{BSAF * f_L}$

Equation 3: $PRG_{sediment} = e\wedge\left[\frac{ln(PRG_{tissue})-\beta_0}{\beta_1}\right] * f_{iron}$

Table 1-10 Summary of Estimated Sediment Concentrations

COPC	Cancer Risk-Based Sediment Concentrations Based on Number of Fish and Crab Meals[(a)] per Year for an Adult (ng/g)								
	56 fish meals per year[(b)]			34 crab meals per year			12 fish or crab meals per year[(c)]		
	1×10^{-6}	1×10^{-5}	1×10^{-4}	1×10^{-6}	1×10^{-5}	1×10^{-4}	1×10^{-6}	1×10^{-5}	1×10^{-4}
TCDD TEQ[(d)]	0.000095	0.0016	0.022	0.00043	0.0050	0.058	0.00080	0.012	▨ 0.19
Total non-dioxin-like PCBs[(d)]	3.2	32	▨ 320	1.6	51	▨ 1600	13	170	▨ 2000
Methylmercury	Classification — C; possible human carcinogen; There is no quantitative estimate of carcinogenic risk from oral exposure.								

	Noncancer Hazard-Based Sediment Concentrations Based on Number of Fish or Crab Meals[(a)] per Year for an Adult (ng/g)		
COPC	56 fish meals per year	34 crab meals per year	12 fish or crab meals per year
TCDD TEQ[(d)]	0.0071	0.019	0.059
Total non-dioxin-like PCBs[(d)]	44	82	230
Methylmercury	550	45,000	▨ 67,000

Concentrations are presented as two significant figures.

ng/g - nanogram per gram (or parts per billion [ppb]).

▨ Indicates that the risk-based value exceeds the NJDEP advisory trigger level and would not be protective or allow additional consumption of fish/crabs. The NJDEP uses ‘do not eat’ values of 0.0077 ng/g, 240 ng/g, and 540 ng/g to set fish consumption advisories for TCDD TEQ, PCBs, and mercury, respectively. Use of PRGs that exceed these NJDEP advisory triggers would not be protective or allow additional consumption of fish/crabs (refer to Table 1-8).

(a) For fish, 56 meals/year = ~1 fish meal every week (consistent with the HHRA ingestion rate [Appendix D]); For crab, 34 meals/year = ~1.5 crab meal every week (consistent with the HHRA ingestion rate [Appendix D]); 12 meals/year = 1 fish or crab meal every month.

(b) The sediment PRGs calculated for 56 fish meals are presented as averages of the white perch and American eel sediment PRGs because information pertaining to fish species preferences and consumption patterns is not available for the FFS Study Area.

(c) Sediment PRGs calculated for 12 fish or crab meals are presented as averages of the sediment PRGs calculated for the white perch, American eel, and blue crab. In the absence of site-specific data to support consumption patterns, equal intake is assumed and accounted for by providing an average of the individual PRGs calculated for the representative species.

(d) For Total non-dioxin-like PCBs and TCDD TEQ, PRGs have been calculated for both carcinogenic and noncarcinogenic health effects. It is recommended that the toxicological effect resulting in the more conservative PRG be used to be protective of both types of health effects.

Table 1-11 Example Calculation of the Sediment PRGs for TCDD TEQ Calculated for 56 Fish Meals

Target Level	**Species**	**Equation Number**	**β_0**	**β_1**	**β_2**	**$PRG_{Sediment}$ Concentration based on Averaging the Fish Species[(a)] (ng/kg)**	**f_{OC} unitless**	**f_L unitless**	**Calculated Tissue Concentration (ng/kg)**	**American Eel fillet Concentration[(b)] (ng/kg)**	**Average Tissue Concentration[(c)] (ng/kg)**	**TCDD TEQ PRG_{Tissue} (pg/g)**
1 x 10^{-6}	American Eel	1	0.0916	0.6344	1.1817	0.095	0.047	0.067	0.071	0.042	0.039	0.039
	White Perch	1	-0.0039	0.9537	1.3431	0.095	0.047	0.050	0.035			
1 x 10^{-5}	American Eel	1	0.0916	0.6344	1.1817	1.61	0.047	0.067	0.43	0.26	0.39	0.39
	White Perch	1	-0.0039	0.9537	1.3431	1.61	0.047	0.050	0.52			
1 x 10^{-4}	American Eel	1	0.0916	0.6344	1.1817	22.4	0.047	0.067	2.3	1.4	3.9	3.9
	White Perch	1	-0.0039	0.9537	1.3431	22.4	0.047	0.050	6.4			
HQ=1	American Eel	1	0.0916	0.6344	1.1817	7.10	0.047	0.067	1.1	0.65	1.4	1.4
	White Perch	1	-0.0039	0.9537	1.3431	7.10	0.047	0.050	2.2			

(a) Sediment concentrations are inputted so that the tissue concentrations when averaged come as close to the TCDD TEQ Tissue PRG as possible. Values listed here are the estimated sediment concentrations provided in Table 1-10.

(b) The American eel fillet concentration is the tissue concentration for the American eel multiplied by the fillet multiplier of 0.6.

(c) The average tissue concentration is the average of the tissue concentrations highlighted in green.

β terms represent exponents on the various factors (*i.e.*, regression coefficients).

f_{OC} – fraction of total organic carbon in the sediment in g organic carbon/ g sediment.

f_L – fraction of lipid in the animal (unitless).

HQ- hazard quotient.

ng/kg – nanogram per kilogram, or parts per trillion (ppt).

$PRG_{Sediment}$ – concentration in sediment.

PRG_{Tissue} – concentration in tissue.

Equation 1: $PRG_{sediment} = e^\wedge\left[\frac{ln(PRG_{tissue})-\beta_0-\beta_2*ln(f_L)}{\beta_1}\right]*f_{OC}$

Table 2-1 Summary of Ecological Receptors Requiring PRG Development

COPEC[a]	Invertebrate		Fish		Bird		Mammal
	Benthos	Crab	Adult[b]	Egg	Adult	Egg	Adult
Mercury	√	√	√	NA	√	NA	√
Total non-dioxin-like PCBs[c]	√	√	√	NA	-	√	√
Total DDx	√	√	√	NA	√	√	-
2,3,7,8-TCDD	√	√	NA	NA	NA	NA	NA
TCDD TEQ (D/F)[d]	NA	NA	√	√	√	√	√
TCDD TEQ (PCBs)[d]	NA	NA	√	-	√	√	√

NA – not available/applicable; "–" indicates that a PRG was not necessary for the particular combination of Contaminants of Potential Ecological Concern (COPEC) and receptor.

(a) As discussed in Section 2, ecological PRGs were not developed for the following COPECs: copper, lead, LMW PAHs, HMW PAHs and dieldrin.

(b) In the BERA, tissue concentrations of both generic fish and mummichog were compared to Critical Body Residues (CBRs) to quantify risks to fish; a PRG was calculated for each selected COPEC with a HQ exceeding one for either receptor.

(c) Included to evaluate the ecological effects of exposure to non-dioxin like PCB congeners; TCDD TEQ (PCBs) is limited to dioxin-like PCB congeners only.

(d) A toxic equivalency approach was not employed in the case of the invertebrate receptors because the Ah binding receptor has not been broadly documented in this class of organisms. Instead, exposure to 2,3,7,8-TCDD was evaluated.

Table 2-2 Summary of Biota PRGs for Whole Body Invertebrate and Fish Tissue

COPEC	Invertebrate[a]			Fish[a]		
	NOAEL	LOAEL	Geometric Mean	NOAEL	LOAEL	Geometric Mean
Mercury	0.048	0.095	**0.068**	0.052	0.26	**0.12**
Total non-dioxin-like PCBs	0.008	0.026	**0.014**	0.17	0.53	**0.30**
Total DDx	0.06	0.13	**0.088**	0.078	0.39	**0.17**
2,3,7,8-TCDD	1.5E-07	1.3E-06	**4.4E-7**	NA	NA	**NA**
TCDD TEQ[b]	NA	NA	NA	8.9E-07	1.8E-06	**1.3E-06**

Units in µg/g (ppm) wet weight; NA – not available/applicable; "–" indicates that a PRG was not necessary for the particular combination of COPEC and receptor; **bolded values** are the values selected to develop sediment PRGs.

(a) Invertebrate and fish CBRs were derived using tissue residue effects data from various benthic and epibenthic macroinvertebrate and estuarine fish species as summarized in the BERA (Appendix D).

(b) Due to consistency in the underlying toxicity basis for the toxic equivalency based on 2,3,7,8-TCDD for dioxin, furan and coplanar PCB congeners, the TCDD TEQ PRGs are applicable to both TCDD TEQ (D/F) and TCDD TEQ (PCBs) COPECs.

Table 2-3 Summary of Biota Tissue PRGs Protective of Indirect Exposures to Fish and Avian Embyros

COPEC	Fish[a]			Avian[b]		
	LCL	UCL	Geometric Mean	NOAEL	LOAEL	Geometric Mean
Total non-dioxin-like PCBs	-	-	**-**	0.059	0.11	**0.080**
Total DDx	-	-	**-**	0.038	0.28	**0.10**
TCDD TEQ	1.0E-05	1.3E-04	**3.6E-05**	8.4E-06	2.1E-05	**1.3E-05**

Units in µg/g (ppm) wet weight; "–" indicates that a PRG was not necessary for the particular combination of COPEC and receptor; **bolded values** are the values selected to develop sediment PRGs.

(a) The benchmarks are based on the lower and upper confidence levels (7.2E-06 and 8.6E-05 µg/g for the LCL and UCL, respectively) for fish eggs derived by the distribution analysis conducted by Steevens *et al*. (2005).

(b) The bird egg NOAELs and LOAELs compiled in the BERA (Appendix D) were adjusted to equivalent whole body fish tissue concentrations using the BMFs included in the analysis.

Table 2-4 Summary of Biota PRGs Based on Wildlife Protection

COPEC	Target Hazard(a)	TRV(b)		Body Weight(c)	Ingestion Rate(c)	SFF(c)	ED(c)	Biota Tissue PRG(d)		
		NOAEL	LOAEL					NOAEL	LOAEL	Geometric Mean
		mg/kg-d		kg	kg/day	%	unitless	mg/kg		
Heron										
Mercury	1.0	0.013	0.026	2.2	0.39	1	0.6	0.13	0.25	0.18
Total DDx	1.0	0.009	0.027	2.2	0.39	1	0.6	0.087	0.26	**0.15**
TCDD TEQ	1.0	2.8E-06	2.8E-05	2.2	0.39	1	0.6	2.7E-05	2.7E-04	8.6E-05
Mink										
Mercury	1.0	0.016	0.027	0.57	0.17	1	1	0.053	0.090	**0.069**
Total non-dioxin-like PCBs	1.0	0.069	0.082	0.57	0.17	1	1	0.23	0.27	**0.25**
TCDD TEQ	1.0	8.0E-08	2.2E-06	0.57	0.17	1	1	2.7E-07	7.4E-06	**1.4E-06**

Mass units in wet weight; **bolded values** are the values selected to develop sediment PRGs.

(a) A Target HQ of 1 was used for all PRG calculations; this would equate to an expected residual risk of 1.

(b) Derivation of the toxicity reference values (TRVs) for aquatic-dependent bird and mammal receptors is discussed in the BERA (Appendix D).

(c) Wildlife exposure parameters (Body Weight, Biota Ingestion Rate, Site Foraging Frequency, and Exposure Duration) are described in the BERA (Appendix D).

(d) Biota tissue PRGs, which are prey tissue concentrations that would result in a Target Hazard of 1, were calculated using Equation 3 and a value of 1 (*i.e.*, 100%) assumed for the P_{biota} term.

Table 2-5 Summary of Biota Tissue PRGs

COPEC	Category[a]						Lowest[b]			
	Residue-Based				Dose-Based[c]					
	Invertebrate	Fish	Fish Embryo	Bird Embryo	Bird	Mammal	Invertebrate	Fish	Wildlife	Overall
Mercury	**0.068**	**0.12**	-	-	0.18	**0.069**	**0.068**	0.12	0.069	0.068
Total non-dioxin-like PCBs	**0.014**	**0.30**	-	**0.080**	-	0.25	**0.014**	0.30	0.080	0.014
Total DDx	**0.088**	**0.17**	-	**0.10**	0.15	-	**0.088**	0.17	0.10	0.088
2,3,7,8-TCDD	**4.4E-07**	NA	NA	NA	NA	NA	**4.4E-07**	NA	NA	4.4E-07
TCDD TEQ	NA	**1.3E-06**	3.6E-05	1.3E-05	8.6E-05	**1.4E-06**	NA	**1.3E-06**	1.4E-06	1.3E-06

Units in µg/g (ppm) wet weight; NA – not available/applicable**;** "–" indicates that a PRG was not necessary for the particular combination of COPEC and receptor; **bolded values** are the lowest tissue PRGs by category and overall.

(a) Biota Tissue PRGs were established for all relevant combinations of evaluated receptors and measures of effect (MEs) evaluated in the BERA and for each, all COPECs determined to have at least one HQ exceeding a value of 1.

(b) The lowest biota tissue PRGs summarized by receptor category and overall lowest ecological value.

(c) The dose based values are prey tissue concentrations estimated to result in a target risk of 1 in wildlife, whereas the residue-based values refer to tissue concentrations in the particular receptor itself (*i.e.*, invertebrate, adult fish, fish embryo and bird embryo).

Table 2-6 Summary of Sediment Benchmark-Based PRGs Protective of Direct Contact Exposure by Benthic Macroinvertebrates

COPEC	Sediment Benchmark[a]		
	Lower-bound	Upper-bound	Geometric Mean
Mercury	0.14	0.48	0.26
Total non-dioxin-like PCBs	0.035	0.37	0.11
Total DDx	0.0016	0.046	0.0086
2,3,7,8-TCDD	0.0000032	NA	0.0000032
TCDD TEQ	NA	NA	NA

Units in µg/g (ppm) dry weight; NA – not available/applicable**.**

(a) Sediment benchmarks used to estimate ecological risks to benthic macroinvertebrates associated with direct contact exposure to sediment (Table 6-4, Appendix D). Lower- and upper-bound sediment screening benchmarks primarily based on 10-day amphipod laboratory bioassays (concentrations associated with 20 and 50 percent probability of observing significant sediment toxicity, respectively; USEPA, 2005). With the exception of 2,3,7,8-TCDD, Effect Range-Low and Effect Range-Median (ER-L and ER-M values; Long et al., 1995; Buchman, 2008) were used for COPECs lacking amphipod logistic regression models. Value is based on the site-specific sediment PRG for oysters based on reproductive impairment as derived by the U.S. Fish and Wildlife Service (Kubiak *et al*., 2007) based on a reproductive effects study by Wintermyer and Cooper, 2003 that identified significant adverse effects on gonadal and embryonic development associated with the bioaccumulation of 2,3,7,8-TCDD in transplanted oysters in Newark Bay and Arthur Kill compared to Sandy Hook. A functional relationship between tissue burdens and sediment exposures was determined using co-located suspended solids chemistry data from the Contamination Assessment and Reduction Project (CARP).

Table 2-7 Summary of Sediment PRGs Based on Ecological Protection

COPEC	Direct Contact[(a)]	Residue-Based[(b)]			Dose-Based	Summary[(c)]			
	Invertebrate	Invertebrate[(d)]	Fish[(e)]	Wildlife[(f)]	Wildlife[(g)]	Invertebrates	Fish	Wildlife	Overall
Mercury	**0.26**	0.66	**0.32**	**-**	**0.074**	0.26	0.32	**0.074**	0.074
Total non-dioxin-like PCBs	0.11	**0.0078**	**0.082**	**0.022**	0.069	**0.0078**	0.082	0.022	0.0078
Total DDx	**0.0086**	0.25	**0.0014**	**0.00030**	0.00098	0.0086	0.0014	**0.00030**	0.00030
2,3,7,8-TCDD	**3.2E-06**	3.3E-06	NA	NA	NA	**3.2E-06**	NA	NA	3.2E-06
TCDD TEQ	NA	NA	**1.1E-06**	1.2E-05	**1.1E-06**	NA	**1.1E-06**	**1.1E-06**	1.1E-06

Units in µg/g (ppm) dry weight; NA – not available/applicable**; bolded values** are lowest values for one or more receptor categories and included in the summary columns and bolding in the summary columns identify the basis for the overall ecological PRG value; "–" indicates that a PRG was not necessary for the particular combination of COPEC and receptor;

(a) Geometric mean values from Table 2-6.

(b) Sediment PRGs were calculated using appropriate equation in Attachment 1.

(c) Summary PRGs are the lowest values across different measurement endpoints (*e.g.*, residue- and dose-based endpoints for wildlife) within a receptor category or across all receptor categories ("overall").

(d) Invertebrate values derived using the invertebrate tissue PRGs (Table 2-5) as input to the appropriate equation in Attachment 1.

(e) Fish values derived using the fish tissue PRGs (Table 2-5) as input to the appropriate equations in Attachment 1; the selected value is the lowest estimated value derived using specified models for white perch, American eel and mummichog.

(f) Based on CBRs for avian embryo tissue (Table 2-3).

(g) Wildlife values derived using the lowest dose-based PRGs (Table 2-5) as inputs to the appropriate equations in Attachment 1.
The sediment PRGs for wildlife were estimated using a general exposure model (Equation 3) that included the consumption of contaminated prey but did not include the incidental sediment ingestion exposure pathway. The resulting sediment PRGs are protective of ecological assessment endpoints for COPECs, such as those included in this analysis, that present primarily a bioaccumulation hazard.

Table 3-1 Background Sediment Concentrations

Analyte	Units	Concentration
Inorganics		
Copper	ng/g	63,000
Lead	ng/g	130,000
Total Mercury (a)	ng/g	720
PAHs		
LMW PAHs	ng/g	7,900
HMW PAHs	ng/g	53,000
PCB Aroclors		
Total non-dioxin-like PCBs	ng/g	460
Pesticides		
Dieldrin	ng/g	5
Total DDx	ng/g	30
Chlordane	ng/g	23
PCDD/F		
2,3,7,8-TCDD (b)	ng/g	0.002

ng/g – nanograms per gram (or parts per billion [ppb]).

(a) All occurrences of mercury are assumed to be methylated for the purposes of this evaluation.

(b) TCDD TEQ (D/F) is represented by the background concentration of 2,3,7,8-TCDD.

Table 3-2 Estimates of the Cancer Risks and Noncancer Health Hazards Associated with Background Sediment Concentrations for Consumption of Fish and Crabs

Ingestion of Fish					
COPC(a)	Adult		Child		Combined Adult/Child
	Risk	Hazard	Risk	Hazard	Risk
TCDD TEQ (D/F)(b)	1×10^{-5}	0.3	5×10^{-6}	0.5	2×10^{-5}
Total non-dioxin-like PCBs	1×10^{-4}	10	6×10^{-5}	16	2×10^{-4}
Methyl mercury	ND	1	ND	2	ND
Ingestion of Crab					
COPC(a)	Adult		Child		Combined Adult/Child
	Risk	Hazard	Risk	Hazard	Risk
TCDD TEQ (D/F)(b)	4×10^{-6}	0.1	2×10^{-6}	0.2	6×10^{-6}
Total non-dioxin-like PCBs	4×10^{-5}	3	2×10^{-5}	5	6×10^{-5}
Methyl mercury	ND	0.2	ND	0.3	ND

ND – not determined because toxicity values are not available for the exposure route.

(a) Cancer risk and noncancer health hazard were estimated for background sediment concentrations for those COPCs with individual cancer risks above 10^{-4} and individual noncancer health hazards above 1.0 in the baseline HHRA (Appendix D "Risk Assessment").

(b) TCDD TEQ (D/F) is represented by the background concentration of 2,3,7,8-TCDD.

Table 3-3 Summary of Estimated Whole Body Tissue Concentrations[(a)] for Ecological COPECs Associated with Background Conditions

COPEC	White Perch	American Eel	Mummichog	Blue Crab
Copper	3.6	0.36	1.3	7.5
Lead	0.20	0.23	0.50	0.12
Mercury	0.13	0.16	0.028	0.070
LMW PAHs	0.32	0.056	0.058	0.017
HMW PAHs	0.19	0.016	0.078	0.024
Dieldrin	0.053	0.014	0.0066	0.0046
Total DDx	0.49	0.16	0.023	0.022
Total non-dioxin-like PCBs	1.7	0.65	0.16	0.21
TCDD	0.0000024	0.00000048	0.00000048	0.00000027

(a) Units in µg/g wet weight (ppm); derived using the sediment tissue bioaccumulation models described in Data Evaluation Report No. 6 (Appendix A).

Table 3-4 Summary of Hazard Estimates to Macroinvertebrates and Fish Receptors Associated with Exposure to Background Conditions

COPEC	**Sediment Benchmarks**		**Tissue/Critical Body Residues**					
			Crab		**Generic Fish**		**Mummichog**	
	Lower-Bound	**Upper-Bound**	**NOAEL**	**LOAEL**	**NOAEL**	**LOAEL**	**NOAEL**	**LOAEL**
Copper	**2**	0.7	**1**	0.6	**6**	**1**	**4**	0.9
Lead	**4**	**1**	0.2	0.05	0.5	0.05	**1**	0.1
Mercury	**5**	**2**	**1**	0.7	**3**	0.6	0.5	0.1
LMW PAHs	**10**	**3**	0.2	0.02	0.7	0.07	0.2	0.02
HMW PAHs	**30**	**6**	**1**	0.1	0.5	0.05	0.4	0.04
Total non-dioxin-like PCBs	**10**	**1**	**30**	**8**	**7**	**2**	**1**	0.3
Dieldrin	**6**	**2**	**3**	0.6	**4**	0.8	0.8	0.2
Total DDx	**20**	0.7	0.4	0.2	**4**	0.8	0.3	0.06
2,3,7,8-TCDD	0.6	0.6	**2**	0.2	**-**	**-**	**-**	**-**
TCDD TEQ (D/F)	**-**	**-**	**-**	**-**	**2**	0.8	0.5	0.3
Total HI	**100**	**20**	**40**	**10**	**30**	**7**	**9**	**2**

(a) Hazards calculated using methodology discussed in the BERA (Appendix D "Risk Assessment"). HQs that are 1 or greater are bolded.

(b) TCDD TEQ (D/F) is represented by the background concentration of 2,3,7,8-TCDD.

Table 3-5 Summary of Hazard Estimates to Wildlife Receptors Associated with Exposure to Background Conditions

COPEC	Wildlife/Dose Models					
	Heron (generic fish diet)		Heron (mummichog diet)		Mink	
	NOAEL	LOAEL	NOAEL	LOAEL	NOAEL	LOAEL
Copper	0.3	0.1	0.2	0.1	0.4	0.2
Lead	**4**	0.4	**4**	0.4	**1**	0.1
Mercury	**1**	0.7	0.6	0.3	**3**	**2**
LMW PAHs	0.09	0.009	0.07	0.007	0.002	0.0006
HMW PAHs	0.3	0.6	6	0.6	0.6	0.1
Total non-dioxin-like PCBs	0.06	0.2	0.05	0.04	**4**	**4**
Dieldrin	**3**	0.02	0.01	0.004	0.6	0.3
Total DDx	0.3	**1**	0.3	0.09	0.1	0.02
TCDD TEQ (D/F)	0.05	0.005	0.02	0.002	**5**	0.2
Total HI	**10**	**3**	**10**	**2**	**10**	**6**

(a) Hazards calculated using methodology discussed in the BERA (Appendix D "Risk Assessment"). HQs that are 1 or greater are bolded.

(b) TCDD TEQ (D/F) is represented by the background concentration of 2,3,7,8-TCDD.

ATTACHMENT 1

Derivation of Sediment PRGs Based on Regression Models

As fully described in the Data Evaluation Report No. 6 “Biota Analysis” (provided in Appendix A), a statistical analysis of tissue chemistry data was conducted for American eel, white perch, blue crab and mummichog (species evaluated in the risk assessments) and corresponding Lower Passaic River and regional surface sediment contaminant concentrations. During this statistical analysis, two statistical regression models were developed to describe the relationship between chemical concentrations in fish or invertebrate tissue and surface sediment. Models were developed for primary risk-driving COPCs and COPECs in whole body biota tissue of American eel, blue crab, and mummichog and for fillet tissue of white perch. In addition to the sediment concentration of a given chemical, lipid content, sediment iron and organic carbon concentrations, and miscellaneous regression model parameters were included in the selected models used to predict biota tissue concentrations. Appendix A presents details regarding the process of model development and evaluation. Note that the regression model derived for mercury was based on tissue chemistry data for elemental mercury, which was more extensively analyzed than methylmercury. It was conservatively assumed that mercury tissue residues in FFS Study Area biota consist entirely of the methylmercury form.

A general logistic regression model presented in Appendix A was used to estimate concentrations of most organic COPC/COPECs in biota. The equation (Equation 1-6 in Appendix A) was rearranged to estimate sediment concentration based on the tissue PRG as follows:

$$C_s = e^\wedge\left[\frac{ln(C_f) - \beta_0 - \beta_2 * ln(f_L)}{\beta_1}\right] * f_{OC} \qquad \text{Equation 1}$$

where:

C_s: Surficial sediment concentration of COPC/COPEC (μg COPC or COPEC/kg sediment)[12]

C_f: Fish or crab tissue concentration (μg COPC or COPEC/kg biota)

f_{OC}: Total Organic Carbon content in surficial sediment (fraction)

f_L: Lipid content of biota (fraction)

β_i: Regression coefficients (unitless).

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[12] The concentration terms for the 2,3,7,8-TCDD regression model are in units of picograms per gram (pg/g).

For some organic COPC/COPEC, a general BSAF model presented in Appendix A (Equation 1-4) was rearranged as follows to estimate the sediment concentration corresponding to a given Total non-dioxin-like PCBs concentration in biota tissue:

$$C_s = \frac{C_f * f_{OC}}{BSAF * f_L} \qquad \text{Equation 2}$$

Appendix A also includes a second general logistic regression model (Equation 1-11) relating sediment concentrations and tissue burdens of inorganic COPC/COPECs in fish and crab. The equation was rearranged as follows to estimate sediment concentration based on the tissue PRG:

$$C_s = e^\wedge{}^{\left[\frac{ln\left(C_f\right)-\beta_0}{\beta_1}\right]} * f_{iron} \qquad \text{Equation 3}$$

where:

C_s: Surficial sediment concentration of COPC/COPEC (mg COPC or COPEC/kg sediment)

C_f: Fish or crab tissue concentration (mg COPC or COPEC/kg biota)

f_{iron}: Iron content of sediment (fraction)

β_i: Regression coefficients (unitless).

Finally, a BAF model presented in Appendix A (Equation 1-9) that was developed to estimate copper concentrations in all three fish species was rearranged as follows to estimate the sediment concentration corresponding to a given copper concentration in tissue:

$$C_s = \frac{C_f}{BAF * f_{iron}} \qquad \text{Equation 4}$$

The site-specific f_{OC} value is the average fractional total organic carbon concentration (*i.e.*, 0.0466 g/g sediment) in surficial sediment samples throughout the FFS Study Area (Table 3-2, Appendix A). Table 1-1 summarizes the specific f_{lipid} values for each tissue and species (*i.e.*, American eel, white perch, mummichog and crab) used to estimate future exposure concentrations as well as develop sediment PRGs. The site-specific f_{iron} value (0.0251 g per g sediment) is the average fractional iron concentration in surficial sediment samples throughout the FFS Study Area (Table 3-2, Appendix A).

Table 1-1 Specific f_{lipid} Values for Each Tissue and Species

Species	Number of Samples	Tissue Type(s)	Average Lipid Fraction (standard deviation)
White perch	11	Fillet (with skin)	0.0226 (0.00700)
American eel	10	Whole body (8), reconstituted whole body (2)	0.0699 (0.0302)
Mummichog	15	Whole body	0.0190 (0.00488)
Blue crab	22	Muscle/hepatopancreas	0.0154 (0.00502)

Estimated BSAF and BAF values for the COPCs and COPECs for which PRGs were established are presented in Appendix A along with all regression model coefficients (*i.e.*, β_i terms).

Finally, Appendix A also includes tissue correction factors to derive sediment PRGs based on fillet (American eel) and whole body (white perch) tissue concentrations as necessary based on human health and ecological exposure assumptions, respectively. Equation 5 was used to estimate American eel fillet tissue concentrations for human health COPCs:

$$C_F = C_W \times \frac{Lipid\text{−}normalized\ mean\ fillet\ concentation\ for\ COPC\ X}{Lipid\text{−}normalized\ mean\ whole\ body\ concentration\ for\ COPC\ X} \times \frac{Fillet\ lipid\ fraction}{Whole\ body\ lipid\ fraction}$$

Equation 5

where:

C_F: Fish fillet tissue concentration (µg COPC or COPEC/g biota)

C_W: Whole body fish tissue concentration (µg COPC or COPEC/g biota)

Similarly, Equation 6 was used to estimate whole body tissue concentrations for ecological COPECs in white perch:

$$C_W = C_F \times \frac{Lipid\text{−}normalized\ mean\ whole\ body\ concentration\ for\ COPEC\ Y}{Lipid\text{−}normalized\ mean\ fillet\ concentration\ for\ COPEC\ Y} \times \frac{Whole\ body\ lipid\ fraction}{Fillet\ lipid\ fraction}$$

Equation 6