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1.0 TECHNICAL APPROACH FOR THE DEVELOPMENT OF HUMAN HEALTH-BASED PRGS

The Phase II Comprehensive Site Assessment (CSA) for the Fireworks Site (the Site) included a baseline Human Health Risk Characterization (HHRC) and a Stage II Environmental Risk Characterization (ERC). Significant potential risks of harm to human health were identified in the HHRC for some Site-user groups relative to certain contaminants in the Site's soil and sediment in specific areas of the Site. In addition, the ERC highlighted a number of cases where conditions reflected Evidence of Biologically Significant Harm or an Indication of Potential for Biologically Significant Harm for some ecological species relative to certain contaminants in the Site's sediments or soil in specific areas of the Site.

This Appendix describes how contaminant and medium-specific preliminary remediation goals (PRGs) were calculated for the Site to establish clear metrics for determining whether a remedial response has achieved a condition of No Significant Risk relative to human health or the environment. Section 1 of this Appendix presents the development of PRGs to address the identified human health risks, while Section 2 presents the development of the environmental risk-based PRGs.

The human health-based PRGs were derived through consideration of Site-specific exposure scenarios and maximum corresponding risk-based concentrations (RBCs), the background concentrations of the constituents in the exposure media, practical analytical quantitation limits (PQLs), and pertinent chemical-specific policy criteria. PRGs were developed for those scenarios that were determined to pose a significant potential risk to human health in the baseline risk characterization. Consequently, PRGs were developed for soil in two depth intervals (0 to 3 and 0 to 6 feet below ground surface [bgs]) and for accessible surficial sediment. No human health-based PRGs were needed for groundwater or surface water, as no unacceptable risks were identified relative to these media.

A chemical-specific risk contribution associated with each identified human health contaminant of potential concern (COPC) addressed in the HHRC (see Table 1-1 of the Preliminary Phase III Remedial Action Plan) for each media of concern was calculated. Decision rules were then established to identify the COPCs that contributed substantially to the risk to the highlighted receptors, as it would serve no useful purpose to calculate PRGs for COPCs that contribute an insignificant amount to the overall receptor totals. These "risk driver" COPCs were operationally defined as the chemicals that individually contributed more than 1×10^{-6} of carcinogenic risk and 0.2 of non-carcinogenic hazard index. Using this definition, this screening process identified the COPCs for which PRGs will be developed as those listed in Table A1-1 (tables are collected at the end of this appendix).

Thus, those COPCs that were in the baseline HHRC, but individually contributed a potential carcinogenic risk contribution to a particular receptor less than 1×10^{-6} or a potential non-carcinogenic hazard index contribution greater than 0.2 were removed from Table A1-1.

1.1 Risk-Based Concentration Calculation

A risk characterization combines the hazard identification, toxicological factors, and exposure assessment to characterize the carcinogenic and non-carcinogenic risk to human health attributable to the projected interaction of a person with an impacted medium. By combining the exposure and toxicity of these components, a concentration of a COPC can be related to a target risk or hazard index goal for a particular receptor. These RBCs were calculated using specified target risk goals to identify the maximum concentration of a constituent that could be present in a medium while still being protective of human

health given specified uses of the Site. The RBCs were calculated using the same exposure factors and toxicity values as were used in the Phase II baseline human health risk characterization (TtEC 2005).

For carcinogenic COPCs, an RBC was calculated that corresponded to a 1×10^{-6} incremental risk of a receptor developing cancer over a lifetime as a result of exposure to that one carcinogen from all complete exposure pathways associated with the medium. For non-carcinogenic COPCs, an RBC was calculated that corresponded to a chemical-specific hazard index contribution of 0.2 (recognizing the potential for additive effects) as the result of exposure to the chemical from all complete exposure pathways associated with the medium. For consistency with the Massachusetts Contingency Plan (MCP), the individual target risk goals were the same as those used to develop the MCP Method 1 Standards. RBCs for soil (0 to 3 ft bgs and 0 to 6 ft bgs) and accessible sediment (bank areas where there is a chance to come in contact with sediment as compared to the middle of a pond) are presented in Tables A1-2 through A1-4, respectively.

1.2 Background Concentrations, Practical Quantitation Limits, and Policy Criteria

The site-specific and exposure-specific RBCs represent the starting point of the PRG development process. The RBCs may be adjusted, as needed, in consideration of local background conditions (so as to not require clean-up to below local background levels), PQLs (so as to not require clean-up to levels below those that can be reliably confirmed analytically), and/or to comply or be consistent with chemical-specific policy-based criteria applicable to the Site circumstances.

The PQL represents the lowest concentration of that chemical that can be routinely and reliably measured in a specified medium using the standard, approved analytical method in a sample that is not excessively contaminated. PQLs may differ by medium for a given chemical constituent. Policy criteria also were considered in the development of the PRGs. A policy criterion value was identified for lead in soil for commercial/industrial uses, as reported in the U.S. Environmental Protection Agency (EPA) Region 9 PRG 2004 Table *(*http://www.epa.gov/*region09/waste/sfund/prg/).* No policy criteria relevant to recreational use were identified.

"Background" is defined in 310 CMR 40.0006 as those levels of oil and hazardous materials (OHM) that would exist in the absence of the disposal site of concern (and meet four other criteria based on specified sources). Four areas of No Historical Fireworks Use were identified when the risk characterization areas were established (i.e., the North, West, East, and Central Areas of No Historical Fireworks Use). Tetra Tech EC, Inc. (TtEC) and Massachusetts Department of Environmental Protection (MassDEP) determined that no activities relating to the Site were conducted in these areas. During the problem formulation process, these areas were considered to reflect background conditions for the Site for soil and groundwater for the purposes of the MCP. In accordance with the MCP, background is considered to include both natural and certain anthropogenic contributions of metals and polycyclic aromatic hydrocarbons (PAHs).

1.2.1 Soil

Although MassDEP has published representative lists of background concentrations for soil, Site-specific background concentrations from the areas of No Historical Fireworks Use were identified and used in the HHRC. For background considerations in soils, only inorganics and PAHs were considered to be potentially present in the background consistent with MCP policy guidance for soil screening methods. Therefore, adjustments for background considerations were limited to those constituents. Site-specific

background samples for soil had concentrations generally close to the MassDEP-published values for "natural" soil (MassDEP 2002).

The background soil samples were collected from one or more of the four Areas of No Historical Fireworks Use. These soil samples were broken up into three depth intervals (0 to 1 feet bgs, 0 to 3 feet bgs, and 0 to 6 feet bgs) consistent with the depth intervals of the Site soil samples collected in each risk characterization area. During Phase IIB, a soil boring (BKGD-01) was advanced in the Central Commercial Area to a depth of 15 feet. Four composite samples were collected at the 0- to 0.5-foot bgs, 0- to 3-foot bgs, 3- to 6-foot bgs, and 6- to 15-foot bgs intervals. In addition, during Phase IID, surficial soil samples were collected from three background areas and analyzed for semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), Target Analyte List (TAL) metals, total mercury, methyl mercury, and explosives. Two background surficial soil samples (CA01[0-0.5] and CA02[0-0.5]) were collected from the Central Area of No Historical Fireworks Use, two background surficial soil samples (WA01[0-0.5] and WA02[0-0.5]) were collected from the Western Area of No Historical Fireworks Use, and one background surficial soil sample (NA01[0-0.5]) was collected from the Northern Area of No Historical Fireworks Use. A summary of the mean and maximum site-specific background soil concentrations are listed in Tables A1-2 and A1-3 for the two depth ranges.

1.2.2 Sediment

No default MassDEP-published background values are available for sediment. Therefore, the analytical results for the Site-specific sediment samples were used to establish background. Site-specific sediment background data were collected during Phases II C and IID from areas that were determined by TtEC and MassDEP not to have been affected by Site-related activities.

Background locations representing a river and a pond were sampled for surface sediments (0-0.5 feet), and the data were pooled. Background sediment samples were collected from the Northern Drinkwater River and Forge Pond. Seven samples were collected from the Northern Drinkwater River: NDRTRA10 (0-0.5), TR S01A-C (0-0.5), TR S01B-L (0-0.5), TR S01C-R (0-0.5), TR S08A-C (0-0.5), TR S08B-C (0-0.5), and TR S08C-L (0-0.5). Six samples were collected from Forge Pond: TR S05A-R (0-0.5), TR S05A-L (0-0.5), TR S05A-C (0-0.5), TR S09I-C (0-1.0), TR S09N-R (0-1.0), and FPTRA10. A summary of the mean and maximum Site-specific sediment background concentrations are listed in Table A1-4.

1.2.3 Groundwater

During Phase IID, background groundwater samples were collected from piezometers PZ-16, PZ-22, and PZ-25 and analyzed for nitroaromatic and inorganic compounds. These results were used as benchmark values in the Phase II CSA analysis. The Phase II CSA analysis determined a level of no significant risk to human health and environmental receptors exists relative groundwater at the Site.

1.2.4 Surface Water

The Phase II CSA determined a level of no significant risk to human health and environmental receptors existed relative to the surface water at the Site. Therefore, a surface water evaluation relative to background was not required.

1.3 Human Health PRG Derivation

Tables A1-2 through A1-4 present the PRGs for soil at two depth intervals (0 to 3 and 0 to 6 feet bgs), and for accessible sediment for recreational use. For each potentially exposed receptor, the tables show

the RBCs that were calculated to meet the specified target risk goals for carcinogenic and non-carcinogenic end points, as appropriate. The tables then identify the most stringent of the RBCs, selecting the lowest calculated value across all potentially exposed receptors for either health effect end point. The tables also identify which receptor (e.g., construction worker, trespasser) and health endpoint (i.e., noncancer impact, cancer impact) was associated with the most stringent RBC.

These tables also present the chemical-specific standards and concentration criteria that were used in the PRG derivation, including the MassDEP-published background values for "natural" soil, Site-specific background values for soils and sediment, the media-specific PQLs, and the pertinent policy criteria. For Site-specific background sediment concentrations, the statistical mean and the maximum concentrations are presented (the mean is used in the PRG derivation for sediment).

In addition, to provide a context for considering the PRGs for soil, the Method 1 Standards for soil, Site-specific background concentrations, and the MassDEP-published background values for soil with fill also are shown. The most appropriate Method 1 Standards for soil and groundwater at this Site were judged to be those associated with the following classifications: S-2/GW-2; S-2/GW-3; S-3/GW-2; and S-3/GW-3. These additional chemical-specific values were included to provide perspective on the most stringent RBCs.

It should be noted that the default Method 1 Standards are higher, in some cases an order of magnitude higher, then the Site-specific RBCs. These two sets of risk-based values differ mainly due to the exposure pathways and toxicity values used in their development. The Method 1 S-2 and S-3 standards do not include the contribution to contaminant intake from the inhalation of particulates exposure pathway, which was considered in the Site-specific RBCs for all receptors. This pathway must now routinely be considered under MassDEP risk characterization guidelines for a construction worker and was judged to be appropriate for the recreational user as well. For several of the COPCs, the inhalation of particulates pathway accounted for over 90 percent of the projected risk reflected in our RBC calculation (for example, 1,1-dichloroethene for outdoor recreational receptors).

Tables A1-2 through A1-4 show the steps in the process used to develop the final PRG values for each COPC. This process is summarized below:

Step A The lowest (most stringent) RBC was identified for every COPC for each medium at the Site to which the identified target receptors are assumed to be exposed.

Step B The value identified in Step A was then compared to background concentration(s) if the COPC is a naturally occurring or ubiquitous chemical in the vicinity of the Site. For sediment, the value in Step A is compared to the mean of the Site-specific background concentration from the river and pond background locations. For soil, the value in Step A is compared to the MassDEP-published background value for "natural" soil. If the value identified in Step A was lower than the applicable background value, the value was adjusted upward to match the background level. Otherwise, the value from Step A was carried forward in the process.

Step C The value identified in Step B was then compared to the PQL for that COPC in that environmental medium. If the value identified in Step B was lower than the PQL, the value was adjusted upward to match the PQL. Otherwise, the value from Step B was carried forward in the process.

Step D Policy criteria or regulatory action levels established for that COPC in a similar exposure setting (e.g., lead) were then considered. The policy criteria were applied, where appropriate. Otherwise, the value from Step C was carried forward in the process.

Step E The value identified in Step D for each COPC in each medium is shown on the last column of Tables A1-2 through A1-4 as the PRG to be used in the Phase III.

The resulting human health PRGs will be used as remediation goals in the Phase III Evaluation of Remedial Action Alternatives for the Site. As shown in Tables A1-2 through A1-4, the soil PRGs are a combination of RBCs, MassDEP-published background concentrations, and PQLs, while sediment PRGs are a combination of RBCs, Site-specific background concentrations, and PQLs.

2.0 TECHNICAL APPROACH FOR THE DEVELOPMENT OF ENVIRONMENTAL-BASED PRGS

Environmental PRGs were determined using the results of both field studies and predictive modeling for the identified receptors and assessment endpoints. PRG development focused on the primary exposure route and source environmental media for the contaminants identified for each constituent of potential ecological concern (COPEC) and assessment endpoint considered. Source environmental media were identified as sediments and surface soils for the assessment endpoints considered.

Linear natural log regression analysis between the primary environmental media of concern (i.e., sediments) and individual trophic levels within the aquatic food chain was used in the PRG calculations. The regression analysis was limited to those data collected for various tissue types sampled in support of the ERC. Environmental media concentrations equivalent to a no observable adverse effects level (NOAEL) or a lowest observable adverse effects level (LOAEL) were then back-calculated using the regression equation for the trophic level of concern. Table A2-1 summarizes the regression equations, coefficient of determination (r^2) and significance levels (p) for the regression analysis between sediment concentrations and the concentrations of the same contaminants in the biota sampled in support of the ERC. For surface soils, the exposure dosage equivalent to the NOAEL and LOAEL dosage was back-calculated using the exposure parameters and the literature-derived bioaccumulation factors used in the ERC.

2.1 COPEC and PRG Selection Criteria

To identify those contaminants requiring the development of media-specific PRGs, a subset of exposure assessment characteristics and risk determination criteria specific to the MCP were applied as follows:

1. Contaminant concentration exceeds the average concentration (mg/kg) in the environmental media and pathway of concern for the applicable reference area;

2. Dosage based on the mean exposure point concentration exceeds a corresponding NOAEL and LOAEL or a media specific exposure point concentration toxicity reference value; and

3. A weight of evidence approach resulted in a risk determination of a risk of biological harm or a potential risk of biological harm to the assessment endpoint evaluated.

Under the MCP, exceedance of a NOAEL alone does not constitute a basis for potential harm but indicates a need to consider other lines of evidence as part of the weight of evidence approach.

Exceedance of a LOAEL value may be considered as a basis for a potential risk of harm. This value was used in the development of the corresponding PRGs. Evidence for harm can be directly determined based upon biological evidence from the field studies used as lines of evidence in the ERC.

2.2 Methodology for Data Analysis and PRG Development

2.2.1 Sediment and Body Burden Relationships in Resident Biota

The bioaccumulation potential of mercury, as methyl mercury (MeHg), and its high biomagnification potential within aquatic food chains required the consideration of trophic relationships and the distribution of MeHg within biota in the aquatic habitats of the Site. Site-specific data related to the observed body burden concentration in resident biota by trophic level and the dominant form of mercury (i.e., MeHg versus total mercury) were used in linear regression analyses with the primary environmental media of concern (i.e., sediments). All data were assessed for normal distribution using the Kolmogorov-Smirnov normality test. Those data that were not normally distributed were log transformed and retested for normal distribution prior to regression analysis. Regression relationships between the concentration of total mercury (THg) and MeHg in sediments and in specific tissues of resident biota were tested to predict the best fit relationship between the two parameters. Linear natural log regression for relating the concentration of mercury forms in sediments and biota were assessed using Equation 1:

$$\text{Ln}(C_{Hg}\ \text{Tissue}) = A + [B * \text{Ln}(C_{Hg}\ \text{Sediment})] \qquad \textbf{(Equation 1)}$$

Where:

$\text{Ln}(C_{Hg}\ \text{Tissue})$	= Natural logarithm of the wet weight concentration of the relevant form of mercury in a specific biota tissue type (mgHg/kg tissue wet weight).
A	= Regression constant (unitless).
B	= Slope from the best fit linear regression relationship between the two concentration data sets (unitless).
$\text{Ln}(C_{Hg}\ \text{Sediment})$	= Natural logarithm of the dry weight concentration of the relevant form of mercury present in the sediment (mgHg/kg sediment dry weight).

The regression equations and constants for each of the trophic levels and tissue types are presented in Table A2-1. To solve for the dry weight equivalent concentration in sediment for the contaminant of interest Equation 2 was used:

$$C_{COPEC}\ \text{Sediment} = \exp[(\text{Ln}(C_{COPEC}\ \text{Tissue}) - A_{COPEC}) / B_{COPEC}] \qquad \textbf{(Equation 2)}$$

Where:

C_{COPEC} Sediment	= The dry weight concentration of the COPEC present in the sediment (mg COPEC/kg sediment dry weight).
$\text{Ln}(C_{COPEC}\ \text{Biota})$	= Natural logarithm of the wet weight concentration of the COPEC in a specific biota tissue type (mg COPEC/kg tissue wet weight).
A_{COPEC}	= COPEC-specific regression constant (unitless).
B_{COPEC}	= COPEC-specific slope from the best fit linear regression relationship between the two concentration data sets (unitless).

For aquatic plants, the log linear regression model developed by Jackson and Kalff (1993) and a percent solids fraction of 0.12 for the conversion from wet weight to dry weight were used to relate sediment concentrations and aquatic plant tissue concentrations.

The regression relationship is given as Equation 3:

$$Log_{10} (C_{COPEC} AQPLT) = 0.12+ [0.76 *Log_{10} (C_{COPEC} Sediment)] \quad \textbf{(Equation 3)}$$

Where:

$Log_{10} (C_{COPEC} AQPLT)$ = Base 10 logarithm of the wet weight concentration of the COPEC in aquatic plant stem and leaf tissue (mg COPEC/kg plant stem and leaf tissue wet weight)

$Log_{10} (C_{COPEC} Sediment)$ = Base 10 logarithm of dry weight concentration of the COPEC present in the sediment (mg COPEC/kg sediment dry weight).

To solve for the dry weight equivalent concentration in sediment for the contaminant of interest, the above equation was solved for the dry weight sediment concentration as Equation 4:

$$C_{COPEC} Sediment = 10^{\wedge} [(Log10 (C_{COPEC} AQPLT) – 0.12) / 0.76] \quad \textbf{(Equation 4)}$$

Where:

$C_{COPEC} Sediment$ = The dry weight concentration of the COPEC present in the sediment (mg COPEC/kg sediment dry weight).

$Log_{10} (C_{COPEC} AQPLT)$ = Base 10 logarithm of the wet weight concentration of the COPEC in aquatic plant stem and leaf tissue (mg COPEC/kg plant stem and leaf tissue wet weight)

The principal form of mercury was different between the abiotic and biotic media with inorganic mercury (excluding MeHg) dominating in the sediments of the aquatic habitats present. For this Site, MeHg in the sediments accounted for less than 1.5 percent of the mercury present in the sediments. However, in biological tissues, MeHg comprised 96 to 100 percent of the mercury present in the tissues of representative fish and invertebrate species collected from the Drinkwater River and Factory Pond. This difference is attributable to the high bioaccumulative and biomagnification potential of MeHg in aquatic food chains.

To better quantify this relationship in support of developing a sediment-based THg PRG, the back-calculation of a THg concentration term relied upon a fractional conversion between MeHg and THg values generated from regression analysis. The regression considered the natural log linear transformation of MeHg concentrations in sediments to the THg concentration in the sediments. The regression equation used is given as Equation 5:

$$Ln (C_{MeHg} Sediment) = -6.427 + [0.62*(Ln C_{THg} Sediment)] \quad \textbf{(Equation 5)}$$

Where:

$Ln (C_{MeHg} Sediment)$ = Natural logarithm of the dry weight concentration of methyl mercury in the sediment (mg MeHg/kg sediment dry weight).

$Ln (C_{THg} Sediment)$ = Natural logarithm of the dry weight concentration of total mercury in the sediment (mg THg/kg sediment dry weight).

2.2.2 Surface Soil and PRG Development

Selection of surface soil-based PRGs relied upon published values from EPA (2003) and Efroymson et al. (1997a) for terrestrial plants and soil invertebrates. For higher trophic level receptors where risk or potential risk of biological harm determinations were found, the generic exposure and bioaccumulation

factors applied were used to back-calculate a soil PRG for the terrestrial assessment endpoints in the ERC.

2.2.3 Aquatic Community PRG Determinations

Three assessment endpoint groups were determined to have a risk or a potential risk for biological harm in the aquatic or wetland environments evaluated:

- Benthic Community
- Fish Community
- Aquatic Reptile Community

The environmental media of concern for each of the above endpoint groups was determined to be sediments in the aquatic and wetland habitats.

2.2.3.1 Benthic Community Assessment Endpoint PRG

The MassDEP currently applies the sediment quality benchmarks employed by McDonald et al. (2000) as the primary screening tool for qualitative assessment of risks to benthic communities. These values, however, do not take into account the specific factors related to sediment chemistry that delimit toxic effects or direct assessment of impact on benthic community structure and function. It is acknowledged that site-specific studies should be used to better identify PRGs for application at hazardous waste sites rather than application of sediment screening level benchmarks. THg and MeHg concentrations in sediments were identified in the ERC (TtEC 2005) as being bioavailable in sediment and bioaccumulative in the aquatic worm *Lumbriculus variegatus*. As a result of this determination, PRGs for THg were developed for riverine, pond and wetland sediments. Environmental benchmarks used in ERCs are available only for THg but not for MeHg. Therefore, the PRG for mercury was based upon THg concentrations.

PRGs for benthic macroinvertebrates were developed using a weight of evidence approach for the measurement endpoints investigated in the ERC for the protection and sustainability of benthic macroinvertebrate communities in aquatic and wetland habitats (TtEC 2005). The level of significance applied for each measurement endpoint used in developing the PRGs for the benthic community follows the listing presented in Table A2-2. Using this approach, the stations demonstrating "no effect" or evidence of significant risk of biological harm were identified and considered for preliminary remediation goals.

Riverine Habitat

Sediments at riverine station ECCTRA10 had no effect on benthic community diversity, structure or function and no negative effect on amphipod, midge, or aquatic worm survival or growth. Toxic potential and bioavailability assessments also predicted minimal effects on the benthic community present. Therefore, the THg concentration in sediments at station ECCTRA10 of 29.0 mg/kg was identified as the PRG for sediments in the riverine habitat (Table A2-3).

Sediments from station ECCTRA12 could have been identified as the preliminary remediation goal for riverine sediments due to lower levels of THg (2.62 mg/kg). However, a negative effect on benthic macroinvertebrate diversity was identified at this station. Unlike the downstream locations, ECCTRA12 had levels of zinc, trichloroethene (TCE), and trans-1,2-dichloroethene (DCE) that exceeded the high

(zinc) and low (TCE, DCE) toxicological benchmarks. As a result of this finding, preliminary remediation goals for DCE, TCE and zinc also will be established for sediments.

A preliminary remediation goal of 152 mg/kg was specified for zinc based on sediments at riverine station EECTRA10 that had no effect on benthic community diversity, structure or function and no negative effect on amphipod, midge, or aquatic worm survival or growth. Preliminary remediation goals of 0.40 and 0.22 mg/kg are specified for DCE and TCE, respectively, based upon the threshold benchmark values from Jones et al. (1996) that were exceeded only by riverine station ECCTRA12 in the sediment screening analysis.

Pond and Wetland Habitats

Sediments at pond stations LUFPTRA11 and MLFPTRA12 exhibited no effect on benthic community diversity, structure or function and had no toxic effect on amphipod, midge, or aquatic worm survival or growth. Therefore, THg concentrations at pond stations LUFPTRA11 and MLFPTRA12 of 40.2 mg/kg and 16.9 mg/kg were identified as potential PRGs for THg in the pond and wetland habitats (Table A2-3). The maximum concentration of THg where effects on benthic communities were not observed (40.0 mg/kg THg) was selected as the PRG for benthic communities in the pond and wetland sediments.

Sediments at pond stations LUFPTRA11 and MLFPTRA12 exhibited no effect on benthic community diversity, structure or function and no negative effect on amphipod, midge, or aquatic worm survival or growth. Therefore, zinc concentrations at pond stations LUFPTRA11 and MLFPTRA12 of 337 mg/kg and 238 mg/kg, respectively, were identified as the site-specific PRG goal for zinc in the pond and wetland habitats (Table A2-3). PRGs of 0.40 mg/kg and 0.22 mg/kg proposed for DCE and TCE in sediments in the riverine habitat were not exceeded at any of the pond or wetland stations.

2.2.3.2 Fish Community Assessment Endpoint PRG

Results of the ERC concluded that a potential risk of harm to piscivorous fish species from MeHg may be present in the aquatic habitats of the Eastern Channel Corridor (ECC) based upon exceedance of a literature-based LOAEL toxicity reference value (TRV) in a surrogate fish species. Forage fish species were not found to exceed a corresponding NOAEL or LOAEL in any of the aquatic habitats sampled.

The lines of evidence considered the use of a residue-based TRV for reproduction endpoints. To determine a meaningful relationship between the source environmental media (i.e., the sediments of the ECC) and the tissue concentrations, regression equations from Table A2-4 were applied to back-calculate a MeHg concentration in sediments that correspond to the NOAEL and LOAEL concentrations in piscivorous fish tissues. To convert this result to a THg value, the regression equation linking MeHg to THg in sediment from Table A2-1 was applied and a THg concentration was calculated as the sediment PRG. Results of that regression resulted in a NOAEL-equivalent PRG concentration of 100 mg/kg THg and a LOAEL-equivalent PRG concentration of 415 mg/kg for the protection of piscivorous fish species.

2.2.3.3 Aquatic Reptile PRG

Numerical criteria for THg in sediments for the protection of aquatic reptiles (i.e., turtles) do not exist. The lines of evidence used in the ERC for the Site and the scientific literature were used to develop a PRG for this receptor group. Results of this review revealed that reptiles appear more tolerant of bioaccumulating contaminants than piscivorous wildlife (Sparling et al. 2000). This may be related to the more diverse diet consisting of fish, aquatic invertebrates, waterfowl, and a minor aquatic plant component. Albers et al. (1986) reported that the snapping turtle populations avoided or were absent

from aquatic habitats with an average concentration of 5.9 mg/kg to 289 mg/kg of THg in sediments. Albers et al. hypothesized this effect to be related to either an elimination of potential prey species or avoidance of the contaminated areas by this species.

Species-specific surveys revealed a reduction in abundance in snapping turtle populations observed in the aquatic habitats of the Lower Drinkwater River and Lily/Upper Factory Pond. No snapping turtles were detected in the habitats of the Lower Drinkwater River. THg concentrations in sediments in the Lower Drinkwater River ranged 0.31 to 277 mg/kg THg with an average THg concentration of 68.4 mg/kg. Abundance of this species was less than the reference population densities in Lily/Upper Factory. In Lily/Upper Factory Pond, THg in the sediments ranged 0.427 to 204 mg/kg with an average of 38.0 mg/kg THg. The population density recovered to comparable numbers to the reference population in Middle/Lower Factory Pond where THg in sediments range 0.989 to 119.0 mg/kg THg with an average concentration of 30 mg/kg THg. A minor increase in the occurrence of shell disease was noted in the population from Middle/Lower Factory Pond, but its frequency of occurrence was determined to be below those observed in highly infected populations (Lovich et al. 1996). The occurrence of infection did not appear as having a significant impact on the relative abundance of this species in Middle/Lower Factory Pond.

No effect on the relative abundance of snapping turtles was observed in the concentration range of 0.989 to 119.0 mg/kg THg and a mean concentration of 30 mg/kg THg in Middle/Lower Factory Pond. Therefore, a maximum sediment NOAEL PRG of 119 mg/kg for THg and a mean concentration of 30.0 mg/kg was selected as the PRG for snapping turtle abundance at the Site. A maximum sediment LOAEL PRG of 204 mg/kg THg and a mean detected concentration of 38 mg/kg THg for snapping turtle abundance is proposed for the Lower Drinkwater River and Lily/Upper Factory Pond.

2.2.4 Semi-Aquatic and Terrestrial Wildlife PRG Development

Eight semi-aquatic or terrestrial wildlife groups were identified to have a potential risk for biological harm in the habitats evaluated at the Site. These groups included:

- Piscivorous Mammals
- Piscivorous Birds
- Omnivorous Mammals
- Omnivorous Birds
- Herbivorous Mammals
- Herbivorous Birds
- Insectivorous Mammals
- Insectivorous Birds

The calculation of wildlife PRGs followed two distinct processes for semi-aquatic and terrestrial wildlife. The principal environmental medium of concern for terrestrial wildlife was surface soils and sediments for semi-aquatic wildlife. The surface water ingestion route and incidental ingestion of soils/sediment for both terrestrial and semi-aquatic wildlife were determined to contribute the smallest doses of COPECs in the species evaluated. The principal exposure route was identified as the dietary ingestion of prey species. Concentrations for semi-aquatic wildlife, whose diet consisted of aquatic invertebrates or forage fish, followed Equation 6:

$$C_{COPEC}\ AQPrey = [(TRV_{COPEC}*BW) / IR] \quad \textbf{(Equation 6)}$$

Where:

C_{COPEC} AQPrey.	= The wet weight concentration of the COPEC in the aquatic prey item ingested (mgCOPEC/kg AQ Prey Item wet wt.).
TRV	= The Toxicity Reference Value (dose) corresponding to a NOAEL or LOAEL (mgCOPEC/kg-AQ Prey Ingested per day).
BW	= Body Weight of the predator receptor being evaluated (kg).
IR	= Daily Ingestion Rate of the aquatic prey items by the predator receptor (kg/day).

NOAELs and LOAELs, body mass (BW) and ingestion rates (IR) corresponded to the receptor-specific parameters applied in the Fireworks ERC. The principal dietary prey items for piscivorous mammals and birds were forage fish, crayfish for omnivorous mammals, aquatic worms and aquatic vegetation for omnivorous birds and aquatic plants for herbivorous birds and mammals. The calculated aquatic prey concentrations were inserted into the prey-specific sediment-biota regression equations to back-calculate a sediment PRG. Table A2-4 provides the summary of calculated sediment PRGs by habitat for the semi-aquatic wildlife receptors evaluated.

Values for terrestrial wildlife receptors relied upon literature based bioaccumulation factors for calculating the dietary dosage contributed by ingested prey items. Concentrations for terrestrial wildlife, whose diet consisted of terrestrial invertebrates, followed Equation 7:

$$C_{COPEC}\ Surface\ Soil = [(TRV_{COPEC}*BW) / (IR*BAF_{COPEC}*MC] \quad \textbf{(Equation 7)}$$

Where:

C_{COPEC} Surface Soil	= The dry weight concentration of the COPEC present in the surface soil (mg COPEC/kg surface soil dry weight).
TRV	= The Toxicity Reference Value (dose) corresponding to a NOAEL or LOAEL (mg COPEC/kg Prey Ingested per day).
BW	= Body Weight of the predator receptor being evaluated (kg).
IR	= Daily Ingestion Rate of the prey items by the predator receptor (kg/day).
BAF	= The soil-to-biota Bioaccumulation Factor (unitless).
MC	= Fraction of solids in the ingested prey item (unitless).

The calculated soil concentration represented the NOAEL- or LOAEL-equivalent concentration of the COPEC in surface soils for the terrestrial receptors evaluated. The short-tailed shrew and American woodcock were the only terrestrial bird and mammal receptors that required the development of a PRG. The primary dietary item for both species was soil invertebrates (i.e., earthworms). Table A2-5 provides the summary of calculated soil PRGs by COPEC for the terrestrial wildlife receptors evaluated.

2.2.5 Soil Invertebrates, Terrestrial Plants and Microbial Processes

PRGs for soil invertebrates were identified from Efroymson et al. (1997b) or from EPA Eco-SSLs (EPA 2002) for those COPECs identified in the ERC (TtEC 2005) (i.e., barium, chromium, copper, lead, nickel, THg and zinc) (Table A2-6). Benchmark concentrations for the toxicity of chemicals to earthworms were available for copper, nickel, and zinc. Because no benchmark was available for THg, an alternative screening benchmark concentration for the toxicity of THg to soil microorganisms and microbial process was utilized.

PRGs for terrestrial plants were identified from Efroymson et al. (1997a) for those COPECs identified in the ERC (TtEC 2005) (i.e., barium, chromium, copper, lead, nickel, THg, and zinc) (Table A2-6). Screening benchmark concentrations for the phytotoxicity of COPECs in soils were available for all COPECs.

2.3 Selection of Environmentally-based Sediment and Surface Soil PRGs

Selection of PRGs was based upon identification of the lowest corresponding PRG calculated for each COPEC. For semi-aquatic and terrestrial wildlife receptors, the selection process considered the lowest LOAEL-equivalent concentration, where available. This selection process adopted the LOAEL as the definitive effects concentration for endpoints having a determination as potential significant biological harm consistent with the MCP process. The PRG selection process did not consider background concentration as a basis for the PRG selection process. Table A2-7 provides the summary and listing of the sediment PRGs by COPEC for the aquatic and semi-aquatic receptors. Table A2-8 provides the summary and proposed soil PRGs by COPEC for the terrestrial receptors.

2.4 Uncertainties in the Development of Environmental PRGs

Development of PRGs must consider the relative effect uncertainty may have on their protectiveness of the resources present. It is generally accepted that a complete and thorough understanding of the dynamics of contaminant cycling in the environment and in food chains can not be determined for every Site. Rather, through the use of site-specific studies and exposure-based food chain modeling, accumulation factors and a basic understanding of trophic level transfer can be inferred. Sources of uncertainty in the development of PRGs are similar to *those* associated with the environmental risk characterization for the Fireworks Site. Major sources of uncertainty have been identified for the ERC that will also apply to the PRG process, these include conceptual model based uncertainty, model uncertainty, parameter uncertainty and uncertainty in natural variation.

2.4.1 Conceptual Model Uncertainty

The conceptual site model (CSM) applied in the ERC and used in the PRG development approach was based upon site specific data and information on the fish and wildlife resources present. These studies also serve as confirmation of exposure pathways and exposure routes through which ecological receptors come into contact with contaminants at the Site. This confirmation validates the exposure assumptions and models applied in the ERC and in development of the PRGs. Surveys of species presence or absence minimized the reliance upon assumptions and provided a basis for confirming if an exposure pathway was complete based upon site specific data. Uncertainty associated with the CSM is considered to be low.

2.4.2 Model-Based Uncertainty

Model-based uncertainty includes that uncertainty associated with the statistical regression models applied in PRG development and models applied in assessing wildlife exposure in the ERC. Models incorporate both site-specific data and empirical data to estimate exposure and to characterize risk for the measurement endpoints used in the weight of evidence approach of the ERC.

The exposure-based modeling used log linear regression to develop *causal* relationships between concentrations of contaminants in sediments and those in harvested biota from the Fireworks Site. These regression relationships were used to estimate a concentration term for the contaminant of interest associated with no significant risk or low risk to resident biota. It is recognized that the regression relationships are limited to the data available for their development and may not expressly represent all

possible scenarios. In addition, regression relationships are mathematical expressions of a trend between two or more variables. While supplying a basis for trend relationships, regression analysis does not confirm cause and effect between two or more variables. The database used to develop the regression equations was associated with body burdens collected from the Site for the biota used in the back calculation process. The coefficient of determination (r^2) values for these regression relationships were in excess of 0.64 and considered to be fully useable based upon the methods described in ORNL (1998).

The PRGs developed for higher trophic level receptors used the wildlife exposure parameters applied in the ERC for the Fireworks Site. The back calculated PRG values considered the exposure route contributing the largest dosage of the contaminant of interest as the basis for the back calculation. The PRG would therefore account for the largest contribution (though not the sole pathway of exposure) of the contaminant of concern. Review of the exposure assessments for aquatic species, semi-aquatic and terrestrial wildlife reveal that the principal exposure route contributed the majority (>95 percent) of the estimated exposure concentration or dosage for mercury and thus would be the most sensitive to active reduction in the environmental source media of concern. Uncertainty effects for reducing exposure though source reduction for the primary exposure route is considered to be low for PRG development.

2.4.3 Parameter Uncertainty

Parameter uncertainty refers to the uncertainties associated with specific values or exposure terms applied in the risk assessment or PRG equations that rely upon an averaged or generic assumption in their application in the exposure assessment.

Estimation of exposure parameters such as ingestion rates and normalized free living metabolic rates were estimated using allometric equations provided by Nagy (1987) and species specific parameters from primary literature summarized in EPA (1993). Such estimates are based upon a range of rates measured from several species from the same class. All estimates are subject to the limits of the equations from which the allometric relationships were derived and applied at the phylogenric order level.

The NOAEL/LOAEL values provided in Sample et al. (1996) are derived for a number of common laboratory and wildlife species based upon toxicity tests with discrete endpoints. Derivation was based upon similarity of phylogenetic groups and relative sensitivity of test species to the wildlife receptors being evaluated. Therefore, some uncertainty can be attributed to the species specific NOAEL/LOAEL values for the receptors considered in this case when based on a similar and not the exact species being evaluated. In an effort to minimize interspecies uncertainties, the observed NOAEL and LOAEL values for the test species were normalized to receptor specific characteristics (i.e., body weight) using the conversion equation proposed by Sample et al. (1996).

2.4.4 Natural Variation Uncertainty

Environmental sampling often relies upon the use of mechanistic or statistical methods to characterize the nature and extent of any *contamination* present in environmental media. The principal contaminant of concern associated with the Fireworks Site for all media was mercury. Sampling involves the collection of environmental concentration data of various media within a discrete period of time where maxima concentrations are anticipated. Because methylation remains linked to microbial activity, the summer months were predicted to account for the greatest degree of methylation of mercury and its ultimate introduction into the food chain of the Drinkwater River and Factory Pond. Therefore, sampling of biological tissues including fish, epifaunal invertebrates and bioassay evaluations were expected to result in a temporal maximum for exposure and bioaccumulation of this element when sampling occurred.

Applying this assumption would have resulted in a biased high concentration and contribute to an overestimate of exposure.

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TABLES

Table A1-1 Identified COPCs for Which PRGs Will be Developed

Soil (0-3 feet bgs)	Soil (0-6 feet bgs)	Sediment (Surficial)
1,1-Dichloroethene	1,1-Dichloroethene	Antimony
Arsenic	Arsenic	Arsenic
Chromium (total)	Benzene	Benzo(a)anthracene
Lead	Cadmium	Benzo(a)pyrene
Trichloroethene	Chromium (total)	Benzo(b)fluoranthene
Vinyl Chloride	Lead	Benzo(k)fluoranthene
	Mercury	Beryllium
	Trichloroethene	Dibenzo(a,h)anthracene
	Vinyl Chloride	Indeno(1,2,3-cd)pyrene
		Lead
		Mercury
		Vinyl Chloride