PENOBSCOT RIVER RISK REDUCTION REPORT

Penobscot River Phase III - Engineering Study

Penobscot River Estuary, Maine

Prepared for:

United States District Court
District of Maine

Prepared by:

Amec Foster Wheeler Environment & Infrastructure, Inc.
511 Congress Street
Portland, Maine 04101

Project No. 3616166052

Final

September 2018

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LIST OF ACRONYMS

Amec Foster Wheeler	Amec Foster Wheeler Environment & Infrastructure, Inc.
AWAC	Area Weighted Average Concentration
BAF	Biota-biota Accumulation Factor
BERA	Baseline Ecological Risk Assessment
BSAF	Biota-sediment Accumulation Factor
CDI	Chronic Daily Intake
Court	United States District Court for the District of Maine
EPC	Exposure Point Concentration
EF	Exposure Frequency
ES	Estuary
g/day	Gram(s) per day
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
IR	Ingestion Rate
kg	Kilogram
LOAEL	Lowest Observed Adverse Effect Level
MDIFW	Maine Department of Inland Fisheries & Wildlife
ME	Maine
MEDEP	Maine Department of Environmental Protection
mg/kg/day	milligram(s) per kilogram per day
MNR	Monitored Natural Recovery
ng/g	Nanograms per gram
NOAEL	No Observed Adverse Effect Level
Phase III	Penobscot River Phase III Engineering Study
PRG	Preliminary Remediation Goals
PRMS	Penobscot River Mercury Study
PRMSP	Penobscot River Mercury Study panel
RfD	Reference dose
SWAC	Surface Weighted Average Concentration
TRV	Toxicity reference value
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

In January 2016, the United States District Court for the District of Maine (the Court) selected Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) to conduct the Penobscot River Phase III Engineering Study (Phase III Engineering Study), to identify and evaluate feasible, effective, and cost-effective measures to remediate mercury in the Penobscot River Estuary. The project area is shown on **Figure 1-1**. The geographic area to be addressed within the Phase III Engineering Study is described by the Court as follows: *"The evaluation will focus in particular on the region from the site of the former Veazie Dam south to Upper Penobscot Bay, including Mendall Marsh and the Orland River."*

The Penobscot River in northern Maine is the second-largest river in New England, with an estuary of 90 square kilometers. A chlor-alkali plant in Orrington, Maine, released mercury into the Penobscot River starting in 1967. The amount of mercury released annually decreased between 1970 and 1982, and decreased further when the plant was closed in 2000. Elevated levels of methyl mercury measured in sediments and biota led to legal action by the Maine People's Alliance in 2000. This group joined with the Natural Resources Defense Council to bring a lawsuit, pursuant to the imminent and substantial endangerment provision of the Resource Conservation and Recovery Act, against HoltraChem Manufacturing Company, LLC and Mallinckrodt, Inc.

The *Risk Reduction Report* incorporates sediment and biota tissue data collected in the Estuary to conduct pre- and post-remediation risk evaluations for human and ecological receptors as part of the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a) for the Phase III Engineering Study. The risk reduction evaluation was performed to aid identification of potentially effective remedies to reduce potential risks from mercury exposure in the Estuary.

ES.1 PRELIMINARY REMEDIATION GOALS

Two sediment preliminary remediation goals (PRGs) for total mercury were evaluated in this *Risk Reduction Report*. The PRGs are 300 nanograms per gram (ng/g) and 500 ng/g. These sediment PRGs are applicable to all sediments within the bioactive zone for estuarine environments (i.e., marsh platform, intertidal, and subtidal sediments). The lower end of the PRG range represents PRGs to meet the MeCDC fish tissue action level, while the upper end of the ranges represent PRGs protective of ecological receptors and the local consumer. These PRGs are proposed for the Estuary as a means to measure remedy effectiveness and risk reduction in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a). The Alternatives Evaluation Report and the Phase III Engineering Study Report provides information on the feasibility and cost of potential remedies. After review of this information, it is assumed that the Court will make risk management decisions relative to the final PRGs to be used in the cleanup of the mercury in the Estuary, and as to the remedies to be implemented.

ES.2 SUMMARY OF REMEDIAL ALTERNATIVES

Remedial alternatives were developed in the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a) based on the constructability assessments and each of the alternatives' ability to achieve the individual PRG scenarios and overall to reduce system-wide surface weighted average concentrations (SWACs) of mercury in sediments.

System-wide remedial alternatives include:

- Alternative 1: Monitored Natural Recovery (MNR)
- Alternative 2: Enhanced MNR

Remedial alternatives for reaches in the Main Channel of the Penobscot River and the Orland River include:

- Alternative 3: Dredging

Remedial alternatives for Mendall Marsh include:

- Alternative 4: Thin-layer capping
- Alternative 5: Amendment Application
- Alternative 6: Dredging in Intertidal and Subtidal Zones & Thin-layer capping on Marsh Platforms

The six alternatives could be implemented as stand-alone remedies system-wide or for specific reaches, or portions of different alternatives could be combined to achieve the system-wide reduction in SWACs of mercury in sediments as discussed in the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a) and Phase III Engineering Report (Amec Foster Wheeler 2018d). These remedial alternatives, excluding Alternative 5: Amendment Application, are evaluated in this *Risk Reduction Report*. Alternative 5: Amendment Application was excluded from the risk reduction evaluation due to the level of unknowns associated with this alternative at this time.

ES.3 DEVELOPMENT OF SURFACE AREA WEIGHTED AVERAGE CONCENTRATIONS

Sediment samples were grouped by zone and reach for the 0 to 0.5-foot depth interval. An area weighted average concentration (AWAC) for each reach/zone was calculated by bootstrapping the sediment samples falling in each reach/zone area and calculating the mean of all the iterations of bootstrapping runs. The AWACs in each area, for which receptor tissue data had been collected as part of the recent biota monitoring efforts, were used to calculate a SWAC representing the area used for the target receptor.

Ecological exposures to impacted sediment are biota-specific. Marsh songbirds are exposed to wetland and intertidal sediments, but not subtidal sediments. Aquatic receptors are exposed to intertidal and subtidal sediments, but not wetland sediments. Thus, the effects of a given remedial alternative are also biota-specific. To account for this effect, pre-, current-, and post-remediation SWACs were calculated on a biota-specific basis.

ES.4 PRE- AND POST-REMEDIATION ASSESSMENT OF HUMAN HEALTH RISK

The human health risk reduction evaluation was based on the results of the Human Health Risk Assessment (HHRA) presented in *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b), which identified potential elevated risk levels for local consumers due to the consumption of locally harvested seafood and waterfowl.

The results of the HHRA indicated that for the local consumer, the biota that has the potential to result in elevated risk levels is the American eel (representing trophic level 4 fish species). Shellfish, American lobster, Atlantic tomcod, rainbow smelt, and American black duck were not identified as a source of potential elevated risk for the local consumer in the HHRA. Shellfish, Atlantic tomcod, and rainbow smelt are not evaluated further as part of the *Risk Reduction Report*. However, because the American lobster and American black duck are associated with local consumption limits, these two biota types, along with the American eel, were further evaluated for the local consumer in the *Risk Reduction Report*.

To quantify risk reduction, concentrations of total mercury in biota tissue were developed using the same approach as used to calculate sediment PRGs in *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b). Concentrations in tissue for the characterization of risk to human health were developed using two different approaches:

- Food web modeling tissue-based approach; and
- Biota-sediment accumulation factor (BSAF) tissue-based approach

Concentrations of mercury in biota tissue were developed using site-specific and species-specific BSAFs and biota-biota (i.e., predator-prey) accumulation factors. In addition, the modelled methyl mercury tissue concentrations were compared to the MeCDC fish tissue action level of 200 ng/g.

ES.5 PRE- AND POST-REMEDIATION ASSESSMENT OF ECOLOGICAL RISK

The ecological risk reduction evaluation was based on the results of the baseline ecological risk assessment (BERA) presented in *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b), which identified potential adverse risk to ecological receptors as a result of mercury exposure in the Estuary. The results of the BERA provide a point of reference for quantification of risk reduction that can be achieved by

each remedial alternative considered in the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a).

Receptors included in the ecological risk reduction evaluation are only biota associated with potential adverse risk (i.e., LOAEL-based HQs above 1.0) based on the results of the BERA. The BERA indicates a potential for adverse risk to marsh songbirds (i.e., Nelson's sparrow and red-winged blackbird) due to exposure to mercury in the Estuary based on blood concentrations. Ecological receptors that were identified as not adversely impacted through exposure to mercury in the BERA are not included in the risk reduction evaluation. The ecological risk reduction evaluation focuses on the Nelson's sparrow and red-winged blackbird and the potential for adverse risk associated with body burden (i.e., mercury accumulation in blood). Concentrations of total mercury in marsh songbird blood were developed using the same methodologies for the tissue concentrations in the human health risk reduction evaluation.

ES.6 SUMMARY OF RISK REDUCTION EVALUATION

The remedial alternatives that would result in a decrease of potential human health and ecological risks to HQs below 1.0 are summarized in the following subsections.

ES.6.1 MAIN CHANNEL OF THE PENOBSCOT RIVER AND THE ORLAND RIVER

The results of the human health risk reduction evaluation for the main channel of the Penobscot River and the Orland River indicated that a decrease in levels of potential risk depended on the species and the remedial alternative. The receptor-specific results of the evaluation are as follows:

Local Consumers

- Potential risks from the consumption of American eel (representing trophic level 4 fish species) by local consumers – For local consumers, Alternative 2: Enhanced MNR (PRG of 300 ng/g) and Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) would result in a decrease in potential risk to acceptable levels. Alternative 2: Enhanced MNR (PRG of 500 ng/g) would result in potential risk levels near 1 (HQs ranging from 1.2 to below 1).
- Potential risks from the consumption of American black duck by local consumers – The remedial alternative that would result in a decrease in potential risk to acceptable levels is Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g). Alternative 2: Enhanced MNR (PRG of 500 ng/g and 300 ng/g) would result in potential risk levels near 1 (HQs ranging from 1.3 to below 1).
- Potential risks from the consumption of lobster by local consumers – Because pre-remediation risks for both the 2014 and 2016 closure areas were below acceptable levels and lobster is an important economic resource for the State of Maine, a more conservative risk reduction approach was undertaken for lobster consumption using an upper-bound BSAF. Under this more conservative risk reduction approach (using the upper bound BSAF), no remedial action is needed to meet acceptable risk levels for the lobster based on the local consumer consumption rates.

MeCDC Fish Tissue Action Level

- Concentration of methyl mercury in American eel tissue (representing trophic level 4 fish species) – Alternative 3: Dredging (PRG of 300 ng/g) would result in a decrease of tissue concentrations to below the MeCDC fish tissue action level of 200 ng/g.
- Concentration of methyl mercury in American black duck tissue – Alternative 3: Dredging (PRG of 300 ng/g) would result in a decrease of tissue concentrations to at or below the MeCDC fish tissue action level of 200 ng/g.
  Concentration of methyl mercury in American lobster tissue – Because pre-remediation risks for both the 2014 and 2016 closure areas were below acceptable levels and lobster is an important economic resource for the State of Maine, a more conservative risk reduction approach was undertaken for lobster consumption using an upper-bound BSAF. Under the more conservative risk reduction approach (using the upper bound BSAF), Alternative 2: Enhanced MNR (PRG of 300 ng/g) and Alternative 3: Dredging (PRG of 300 ng/g) would result in a decrease to below 200 ng/g, with the exception of the 2016 lobster closure area when assuming the upper bound BSAF.

ES.6.2 MENDALL MARSH

The results of the human health and ecological risk reduction evaluation for Mendall Marsh indicated that a decrease in levels of potential risk dependent on the receptor (human or ecological) and the remedial alternative. The receptor-specific results of the evaluation are as follows:

Local Consumers

- Potential risks from the consumption of American black duck by local consumers – The BSAF approach risk level for black duck has an HQ less than 1.0. The food chain black duck risk has an HQ greater than 1.0. The remedial alternatives that would result in a decrease in potential food chain risk to acceptable levels for Mendall Marsh are Alternative 4: Thin-layer capping and Alternative 6: Dredging and thin-layer capping.

MeCDC Fish Tissue Action Level

- Concentration of methyl mercury in American black duck tissue – The remedial alternatives that would result in a decrease in methyl mercury tissue concentration to below 200 ng/g for Mendall Marsh are Alternative 4: Thin-layer capping (BSAF approach only) and Alternative 6: Dredging and thin-layer capping (BSAF approach only).

Ecological Receptors

- Potential ecological risks for the Nelson's sparrow and red-winged blackbird – The remedial alternative that would result in a decrease in potential LOAEL risk levels below

1.0 for Mendall Marsh – West and Mendall Marsh – East is Alternative 6: Dredging and thin-layer capping. The additional remedial alternatives which would result in reduction of potential risk levels to near 1.0 (HQs ranging from 1.5 to below 1.0) are Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) for Mendall Marsh - West and Alternative 4: Thin-layer capping for both Mendall Marsh – East and West.

ES.6.3 SOUTHERN COVE

The results of the human health and ecological risk reduction evaluation for Southern Cove indicated that a decrease in levels of potential risk depend on the species and the remedial alternative. The receptor-specific results of the evaluation are as follows:

Local Consumers

- Potential risks from the consumption of American eel (representing trophic level 4 fish species) by local consumers – For local consumers, Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) would result in potential risk levels below 1.0 in Southern Cove. Alternative 2: Enhanced MNR (PRG of 300 ng/g) would result in potential risk levels near 1 (HQs ranging from 0.88 to 1.3).
- Potential risks from the consumption of American black duck by local consumers – No remedial alternatives based on the food web approach would result in potential risk levels below 1.0 in Southern Cove. Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) would result in the lowest potential risk levels for local consumers (HQs ranging from 0.75 to 1.6), while Alternative 2: Enhanced MNR (PRGs of 500 ng/g and 300 ng/g) would result in a slightly higher risk (HQs ranging from 0.84 to 1.9).

MeCDC Fish Tissue Action Level

- Concentration of methyl mercury in American eel tissue (representing trophic level 4 fish species) – Alternative 3: Dredging (PRG of 300 ng/g) would result in methyl mercury tissue concentrations below 200 ng/g for the American eel.
- Concentration of methyl mercury in American black duck tissue – None of the remedial alternatives would result in a decrease in methyl mercury tissue concentration to below 200 ng/g for Southern Cove. However, Alternative 3: Dredging (PRG of 300 ng/g) would result in the lowest potential tissue concentrations.

Ecological Receptors

- Potential ecological risks for the Nelson's sparrow – No remedial alternatives would result in potential risk levels below 1.0 in Southern Cove. The remedial alternative that would result in the lowest LOAEL HQs is Alternative 3: Dredging with a PRG of 300 ng/g, which would result in a range of HQs from 1.5 to 2.5.
- Potential ecological risks for the red-winged blackbird – No remedial alternatives would result in potential risk levels below 1.0 in Southern Cove. The remedial alternative that

would result in the lowest LOAEL HQs is Alternative 3: Dredging with a PRG of 300 ng/g, which would result in a range of HQs from 1.8 to 2.5.

1.0 INTRODUCTION

In January 2016, the United States District Court for the District of Maine (the Court) selected Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) to conduct the Penobscot River Phase III Engineering Study (Phase III Engineering Study), to identify and evaluate potential and cost-effective measures to remediate mercury in the Penobscot River Estuary (the Estuary). The project area is shown on **Figure 1-1**. The geographic area to be addressed within the Phase III Engineering Study is described by the Court as follows: "The evaluation will focus in particular on the region from the site of the former Veazie Dam south to Upper Penobscot Bay, including Mendall Marsh and the Orland River." This Penobscot River *Risk Reduction Report* presents the results of the residual risk assessments based on the evaluation of remedial alternatives that could potentially be implemented to reduce risks posed to humans and ecological receptors by mercury contamination present in the Estuary. The goal of remedy implementation is to reduce ecological and human health risks resulting from the discharge and subsequent accumulation of mercury in the sediments of the Estuary.

The *Risk Reduction Report* incorporates sediment and biota tissue data collected in the Estuary to conduct pre- and post-remediation risk evaluations for human and ecological receptors as part of the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a) for the Phase III Engineering Study.

1.1 PRELIMINARY REMEDIATION GOALS

Two sediment preliminary remediation goals (PRGs) for total mercury were evaluated in this *Risk Reduction Report*. The PRGs are 300 nanograms per gram (ng/g) and 500 ng/g and are applicable to all sediments within the bioactive zone for estuarine environments (i.e., marsh platform, intertidal, and subtidal sediments). The lower end of the PRG range represents PRGs to meet the MeCDC fish tissue action level, while the upper end of the ranges represent PRGs protective of ecological receptors and the local consumer. These PRGs are proposed for the Estuary as a means to measure remedy effectiveness and risk reduction in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a). The Alternatives Evaluation Report and the Phase III Engineering Study Report provide information on the feasibility and cost of potential remedies. After review of this information, it is assumed that the Court will make risk management decisions relative to the final PRGs to be used in the cleanup of the Estuary mercury, and as to the remedies to be implemented. For further discussion on the PRGs, refer to the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* report (Amec Foster Wheeler 2018b).

While PRGs have been developed for total mercury and methyl mercury (Amec Foster Wheeler 2018b), the evaluation of risk reduction presented in this report focuses on the PRGs for total mercury. Methyl mercury data are included in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a) as a screening tool for prioritizing (if necessary) remedial decisions between

reaches/zones with potentially similar (and/or lower) area weighted average concentrations (AWACs) of total mercury, but elevated concentrations of methyl mercury. Reductions in total mercury concentrations should result in reduced methylation rates and a decreased potential for biological uptake and trophic transfer of methyl mercury because the rate at which mercury is methylated is related to the concentration of total mercury present in sediment (Cossa et. al. 2014). The decrease in sediment concentrations from pre- to post-remediation activities represents a "step-down" in sediment exposure point concentrations (EPCs) and does not contain any indication of recovery time.

1.2 SUMMARY OF REMEDIAL ALTERNATIVES

Remedial alternatives were developed in the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a) based on the constructability assessments and each alternative's ability to achieve the individual PRG scenarios and overall to reduce the system-wide surface weighted average concentrations (SWACs) of mercury in sediments.

System-wide remedial alternatives include:

- Alternative 1: Monitored Natural Recovery (MNR)
- Alternative 2: Enhanced MNR

Remedial alternatives for reaches in the Main Channel of the Penobscot River and the Orland River include:

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Remedial alternatives for Mendall Marsh include:

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- Alternative 5: Amendment Application
- Alternative 6: Dredging in Intertidal and Subtidal Zones & Thin-layer capping on Marsh Platforms

The six alternatives could be implemented as stand-alone remedies system-wide or for specific reaches, or portions of different alternatives could be combined to achieve the system-wide reduction in SWACs of mercury in sediments as discussed in the Alternatives Evaluation Report (Amec Foster Wheeler 2018a). These remedial alternatives, excluding Alternative 5: Amendment Application, are evaluated in this Risk Reduction Report. Alternative 5: Amendment Application was excluded from the risk reduction evaluation due to the level of unknowns associated with this alternative at this time.

2.0 DEVELOPMENT OF SURFACE AREA WEIGHTED AVERAGE CONCENTRATIONS

2.1 SWAC CALCULATION METHODOLOGY

Sediment samples were grouped by zone and reach for the 0– to 0.5-foot depth interval (biologically active zone). An AWAC for each reach/zone was calculated by bootstrapping the sediment samples falling in each reach/zone area and by calculating the mean of the multiple iterations of bootstrapping runs. The AWACs in each area, for which receptor tissue data had been collected as part of the recent biota monitoring efforts, were used to calculate SWAC representing the area used for the target receptor. The equation to calculate the SWAC is as follows:

$$SWAC = \frac{\sum_1^n AWAC_n * Area_n}{\sum_1^n Area}$$

For reach/hydrodynamic zone units for which no field data were available for the 0–0.5 foot depth increment, an estimated bootstrap mean was assigned to the unit based on the bootstrap mean calculated for the nearest relevant hydrodynamic unit. For example, no data were available for the intertidal area on the west side of the Verona West reach. A bootstrap mean of 885.5 ng/g was assigned from the Bucksport Intertidal West zone, which is a relevant, upstream intertidal hydrodynamic zone unit.

Ecological exposures to impacted sediment are biota-specific. Marsh songbirds are exposed to wetland and intertidal sediments, but not subtidal sediments. Aquatic receptors are exposed to intertidal and subtidal sediments, but not wetland sediments. Thus, the effects of a given remedial alternative are also biota-specific. To account for this effect, pre-, current, and post-remediation SWACs were calculated on a biota-specific basis.

2.2 SWAC AREAS

Sediments used to generate the SWACs were receptor-specific, accounting for habitat type and potential exposure. **Figures 2-1 through 2-8** depict the subtidal, intertidal, surface deposit, and wetland platform sediments within the exposure areas used to calculate the SWACs for each receptor in the risk reduction evaluation. Finfish and lobster sediments included subtidal and intertidal sediments (**Figures 2-1 through 2-2b**). American black duck (**Figures 2-3a and 2-3b**) and marsh songbird (**Figure 2-4**) sediments included wetland sediments and intertidal sediments. Mendall Marsh-West SWACs include Mendall Marsh Southwest and W-17-N sediments. **Figures 2-5 and 2-6** depict the Southern Cove excavation footprint for the applicable fish and avian receptors, respectively. **Figures 2-7 and 2-8** depict the Orland River area for the applicable fish and black duck receptors, respectively.

2.3 Pre-Remediation SWAC Calculation

Pre-remediation SWACs for each reach by elevation zone (marsh, subtidal, and intertidal) were estimated based on the respective surface areas (adjusted for areas of exposed bedrock) and total mercury bootstrap mean concentrations (i.e., AWAC).

2.4 Current Southern Cove Post-Remediation SWAC Calculation

A "current" post-remediation SWAC was calculated for the area of Southern Cove to represent SWACs for that area after ongoing remedial activities were completed and before implementation of the remedies proposed in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a) or Phase III Engineering Report.

2.5 Post-Remediation SWAC Calculation

Post-remediation SWACs were estimated using pre-remediation AWACs (bootstrap mean concentrations), surface areas of the reach/zones, and the anticipated reduction in sediment mercury concentrations in relation to proposed remedial alternatives described in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a).

The methodology and assumptions used to estimate biota-specific post-remediation SWACs are described below.

Alternative 1: MNR

No immediate change in SWACs was anticipated. Thus, pre-remediation and post-remediation SWACs are the same.

Alternative 2: Enhanced MNR

Enhanced MNR is a sediment management approach that relies on addition of clean sediments to the mobile pool to enhance natural recovery processes. Post-remediation SWACs were estimated based on the following assumption:

- Addition of sufficient clean material to the mobile pool to reduce the concentration of the mobile pool to the target PRG (i.e., 500 ng/g or 300 ng/g). Volumes for this change in the mobile pool concentration are provided in the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a). The change in the mobile pool concentrations would reduce the concentration to the target PRG in the top 3 inches of sediment in the intertidal and subtidal zones of the main channel of the Penobscot River (Main Channel) and Orland River.

The following equation was used to estimate the post-remediation SWACs:

$$Post\text{-}Remediation\ SWAC = \frac{(Pre\text{-}SWAC\ +\ PRG)}{2}$$

Where: *PRG* = 500 ng/g or 300 ng/g

Alternative 3: Dredging

Dredging is an active remedial approach that removes mercury-contaminated sediment to achieve a permanent reduction in mercury concentrations within a short period. This alternative has two scenarios:

A) Surface deposits and 12 zones removed to reach a target PRG of 500 ng/g (most reach/zones remain intact). In addition, Alternative 3: Dredging includes the excavation of the pocket and fringing marshes along the main Estuary channel (i.e. Frankfort Flats marsh, Orland River marsh, Verona East marsh, Verona Northeast marsh, and Winterport Marsh) and excludes Mendall Marsh.
B) Surface deposits and most subtidal and intertidal reach/zones removed (12 are not removed) to reach a target PRG of 300 ng/g. In addition, Alternative 3: Dredging includes the excavation of the pocket and fringing marshes along the main Estuary channel (i.e. Frankfort Flats marsh, Orland River marsh, Verona East marsh, Verona Northeast marsh, Winterport Marsh, and Orrington Marsh) and excludes Mendall Marsh.

Post-remediation SWACs in the reach/zones were assigned a value of 115 ng/g and the surface deposits were assigned a value of 500 ng/g (Scenario A) or 300 ng/g (Scenario B) to account for mixing of clean and other riverine sediments. The concentration of 115 ng/g applied as the post-remediation concentration is an estimate based on the assumptions that: (1) with an average system-wide sedimentation rate of approximately 0.5 centimeters per year (0.20 inches per year) (Amec Foster Wheeler 2018c) and a mobile sediment total mercury concentration of 760 ng/g (value is an average of unconsolidated sediment/mobile sediment from Table 3-2 and 3-3 of the Alternatives Evaluation Report [Amec Foster Wheeler 2018a]), in 10 years, the weighted average total mercury concentration within the biologically active zone in areas that have been dredged and backfilled would be approximately 140 ng/g; and (2) the average concentration of total mercury on particulate matter entering the system from upgradient sources is 220 ng/g. Additionally, Scenarios A and B use the proposed remediation goals as the replacement concentrations for the removal of surface deposits assuming that sediment transport moves fresh material into these areas.

Alternative 4: Thin-Layer Capping

Thin-layer capping is an in-place sediment management approach that relies on addition of clean sediment placed on the surface of the marsh to create a clean surface layer above the existing sediment that reduces exposure of biota to contaminants. Capping would occur over 50 percent of Mendall Marsh at a depth of 3 inches. One hundred percent of Mendall Marsh with an elevation from 2 to 7.5 feet based on NAVD88 and approximately 20 percent of Mendall Marsh at an elevation greater than 7.5 feet would compose the marsh area capped, which is 50 percent of the marsh platform. Post-remediation SWACs in the capped portions of Mendall Marsh were assigned 20 ng/g (concentration of clean cap material) and the other 3 inches of these areas were assigned the 0- to 3- inch bootstrap mean. Uncapped portions of Mendall Marsh retained the value of the

bootstrap mean for the 0- to 6-inch zone. Note that implementation of thin-layer capping could, however, be expanded to other marsh areas in the Estuary.

Alternative 5: Amendment Application

Amendment application is an in-place sediment management approach that relies on the broadcasting of amendments onto the surface of the marsh platform to provide a surface layer of carbon that would reduce biological uptake of methyl mercury in surface sediments. No SWACs or risk reduction was calculated.

Alternative 6: Dredging in Intertidal and Subtidal Zones & Thin-Layer Capping

This alternative includes dredging of sediments in the intertidal and subtidal zones in Mendall Marsh with thin layer capping on the marsh platform to meet a target PRG of 300 ng/g in Mendall Marsh. Dredging and capping would occur as described above.

2.6 CALCULATED SWACS

The pre-remediation and post-remediation SWACs are summarized on **Table 2-1** by receptor, area, and remedial alternative. The decrease in sediment concentrations from pre- to post-remediation activities shown in the pre- and post-remediation SWACs represents a “step-down” in sediment exposure point concentrations (EPCs) and does not contain any indication of recovery time.

SWAC calculations for Southern Cove were run for three different scenarios: 1) pre-remediation, 2) current conditions, and 3) post-remediation. Samples within the Southern Cove remediation footprint were separated from the rest of the ribbons of the reach. Samples that were removed during ongoing remediation activities were excluded from bootstrap mean concentrations between the pre-remediation and current conditions scenarios. Additional samples as part of the ribbons that might be removed in the remedial alternatives were excluded in the post-remediation SWAC calculation.

3.0 PRE- AND POST-REMEDIATION ASSESSMENT OF HUMAN HEALTH RISK

3.1 INTRODUCTION

This human health risk reduction evaluation was based on the results of the Human Health Risk Assessment (HHRA) presented in the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* report (Amec Foster Wheeler 2018b), which identified potential elevated risk levels for local consumers due to the consumption of locally harvested seafood and waterfowl. The results of the HHRA provide a point of reference for quantification of risk reduction that can be achieved by each remedial alternative considered in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a).

3.1.1 Results of the Baseline Human Health Risk Assessment

As part of the evaluation of risk reduction, the results of the HHRA portion of the baseline risk assessment report (Amec Foster Wheeler 2018b) were used to select which receptors/pathways/biota of concern were potentially associated with elevated levels of risk that would require remediation. Potential risks were quantified to characterize risk from the consumption of local biota by adult and younger child local consumers:

Local consumers are defined as individuals who consume locally caught lobster, shellfish (i.e., clams and blue mussels), finfish, and duck as part of their diet.

The results and conclusions of the baseline HHRA are listed in **Table 3-1** and are as follows:

- Noncarcinogenic hazard from the ingestion of inorganic mercury in biota does not exceed acceptable hazard levels for the American lobster, blue mussels, soft-shell clams, rainbow smelt, Atlantic tomcod, and American black duck for all locations. Therefore, exposure to inorganic mercury is not a concern for human receptors and requires no further evaluation.

- Noncarcinogenic hazard from ingestion of biota methyl mercury does not exceed acceptable hazard levels for blue mussels and soft-shell clams for all locations. Therefore, exposure to methyl mercury in shellfish (i.e., blue mussels and softshell clams) is not a concern for human receptors and requires no further evaluation.

- Noncarcinogenic hazard from ingestion of biota methyl mercury does not exceed acceptable hazard levels for the American lobster, rainbow smelt, Atlantic tomcod, and American black duck for all locations.

- Noncarcinogenic hazard from ingestion of biota to methyl mercury in the American eel (trophic level 4 fish) exceeds the target HQ of 1 near sampling location BO-04. For all other sampling locations, the noncarcinogenic hazard was below the target HQ of 1.

- Noncarcinogenic hazard from ingestion of biota to methyl mercury in the American black duck slightly exceeds the target HQ of 1 near sampling location ES-13, but is at or below the target HQ of 1 for all other sampling locations.

Based on the above results, noncarcinogenic hazard to human health from methyl mercury in the Estuary under current and future use scenarios are expected to have the potential to exceed an acceptable noncarcinogenic hazard for the American eel (trophic level 4 fish).

3.1.1.1 Biota of Concern

The results of the HHRA indicated that for the local consumer, the biota that have the potential to result in elevated risk levels is the American eel. Shellfish, American lobster, Atlantic tomcod, rainbow smelt, and American black duck were not identified as a source of potential elevated risk for the local consumer in the HHRA. For this reason, shellfish (i.e., blue mussels and softshell clams), Atlantic tomcod, and rainbow smelt are not further evaluated in the *Risk Reduction Report*. Because both the American lobster and American black duck are associated with local consumption limits, both biota types were evaluated for the local consumer as part of the *Risk Reduction Report*.

3.1.2 Exposure Scenarios of Concern

Potential receptors, exposure pathways, and qualitative/quantitative evaluation methodologies were documented in the conceptual site model in **Figure 3-1**. As shown on **Figure 3-1**, a single receptor population is considered in the HHRA, local consumers of fish and other biota tissue.

For each receptor type, age-specific consumption rates were derived for adults and for younger children (1–7 years of age) using the Maine Department of Environment and Protection (MEDEP) assumption (MEDEP 2011) that younger child consumption rates are equal to 30 percent of the adult consumption rates. Children less than one year of age (i.e., infants) were not evaluated because they were unlikely to consume the evaluated biota as part of their normal infant diet. These consumption rates were then applied to representative sampled species that are likely to be consumed by local residents and/or represent a class of biota that is likely to be consumed by local residents and are associated with exceedances of the target HQ of 1 in the HHRA portion of the baseline risk assessment report (Amec Foster Wheeler 2018b).

Local seafood consumers would rely heavily on locally caught seafood as part of their diet. For local consumers, an adult finfish tissue consumption rate of 21 grams per day (g/day) was based on estimation of fish intake rates of anglers in Maine (see Table 10-72 of the U.S. Environmental Protection Agency (USEPA) Exposure Factors Handbook [EPA 2011]). Based on this, the calculated child local consumer finfish consumption rate (30% of the adult consumption rate) is 6.3 g/day.

The local consumer consumption rates for lobster were taken from the results of a dietary survey taken for the Quincy Bay Superfund site in Massachusetts (Cooper et al. 1991). The results of

this survey indicated that adult "Local Consumers" (i.e., the average household) would ingest 1.7 g/day of lobster tissue (trophic level 3) (about 6-7 meals/year), which results in a calculated younger child consumption rate of 0.51 g/day.

The consumption of wild-caught duck by local hunters was evaluated using State waterfowl consumption advisories for the lower Estuary. For an adult, the Maine Department of Inland Fisheries & Wildlife recommends a safe eating guideline of no more than two waterfowl meals per month for waterfowl taken from the lower Estuary (MDIFW 2017a). Per the same recommendations, children under the age of eight and pregnant or nursing women should not eat any waterfowl taken from the area.

3.1.2.1 Exposure Areas of Concern

Based on the results of the HHRA, the reduction of risk will be evaluation using SWACs for the following exposure areas:

- Lobster
  - 2014 closure area
  - 2016 closure area
- American Eel
  - Freshwater Area (Bangor to Frankfort Flats, intertidal and subtidal sediment)
  - Bangor
  - Orrington
  - Frankfort Flats
  - Orland River and East Channel
  - Southern Cove (from BO-04 to OB-05 and full width of river)
- American Black Duck
  - Whole river
  - Mendall Marsh
  - Verona East
  - Orland River and East Channel
  - Southern Cove (from BO-04 to OB-05 and full width of river)

3.1.3 Concentrations of Mercury in Tissue

Target risk reduction concentrations of total mercury in biota tissue were developed using the same approach as used to calculate sediment PRGs in the baseline risk assessment report (Amec Foster Wheeler 2018b). Concentrations in tissue for the characterization of risk to human health were developed using two different approaches:

- Food web modeling tissue-based approach; and
- Biota-sediment accumulation factor (BSAF) tissue-based approach

Concentrations of mercury in biota tissue were developed using site-specific and species-specific BSAFs and biota-biota (i.e., predator-prey) accumulation factors (BAFs). The site-specific BSAFs and BAFs were developed as part of the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b) and are summarized in **Appendix A**. In addition, because the lobster is an important economic resource for the State of Maine, additional tissue concentrations were calculated for the BSAF approach using an upper bound BSAF. The pre- and post-remediation risks calculated using the upper bound BSAF would represent the most conservative scenario for concentrations of mercury in lobster tissue. The food web approach was not addressed using the upper bound BSAF because other lobster are a small percentage (14 percent) of the overall lobster diet so any effect would be minimal. The models and calculated tissue concentrations are presented in **Appendix B**. Note that developed tissue concentrations for total mercury were multiplied by species-specific percent concentrations of methyl mercury presented in **Appendix A** to develop species-specific methyl mercury tissue concentrations. The concentrations of total mercury and methyl mercury in tissue are listed in **Table 3-2**. In addition, the pre- and post-remediation calculated tissue concentrations were compared to the Maine fish tissue action level of 200 ng/g methyl mercury.

3.1.3.1 Food-Web Approach

Concentrations of total mercury in biota tissue for aquatic species (i.e., represented by lobsters, forage fish, and predatory fish) and wetland-dependent birds (i.e., represented by the American black duck) were calculated using the SWAC (termed C_{SED} in equation below) and estimated exposure using the following equation:

$$C_{TIS}(\frac{ng}{g}) = C_{SED}\,(\frac{ng}{g}) \times \sum_{p}^{n=p} BSAF_p \times \left(BAF_p \times DC_p\right)$$

Where:

- C_{TIS} = Concentration of total mercury in tissue (ng/g)
- C_{SED} = Concentration of total mercury in sediment (ng/g, dry weight [dw])
- $BSAF_P$ = Species-specific BSAF (unitless) of a prey item
- BAF_P = Species-specific BAF (unitless) of a prey item
- DC_P = Dietary Composition (%) of a prey item

The dietary compositions for each receptor used in the tissue concentration calculations are presented in **Appendix B**.

3.1.3.2 BSAF Approach

In addition to developing concentrations of total mercury in biota tissue based on food web modeling, concentrations of total mercury in biota tissue based on the biota-specific BSAFs were

also calculated using SWAC values (termed C_{SED} in equation below) and estimated exposure using the following equation:

$$C_{TIS}\ (\frac{ng}{g}) = C_{SED}(\frac{ng}{g}) \times \sum_{p}^{n=p} BSAF$$

Where:

- C_{TIS} = Concentration of total mercury in tissue (ng/g)
- C_{SED} = Concentration of total mercury in sediment (ng/g, dry weight [dw])
- BSAF = Species-specific BSAF (unitless) of a biota type

3.1.4 Estimated Daily Intake

For the consumption pathways, the estimated human exposure or intake is calculated as a chronic daily intake (CDI), which is expressed in terms of mass of the constituent of potential concern taken into the body per unit of body weight per unit of time (expressed in units of milligrams per kilogram per day [mg/kg/day]). The CDI for each receptor and exposure pathway is a function of the EPC, consumption rate, exposure frequency and duration, body weight, and time. The chronic daily intake for tissue consumption exposure scenarios was calculated using the default equation found in the EPA Risk Assessment Guidance for Superfund Part A (EPA 1989). The equation used to calculate intake of mercury from the consumption of fish tissue is as follows:

$$CDI\ (\frac{mg}{kg-day}) = \frac{EPC\ \left(\frac{mg}{kg}\right) x\ EF\ \left(\frac{days}{year}\right) x\ ED\ (years) x\ IR\ \left(\frac{mg}{day}\right) x\ 0.000001\ (\frac{kg}{mg})}{BW\ (kg) x\ AT\ (years) x\ 365\ (\frac{days}{year})}$$

Where:

CDI – chronic daily intake (mg/kg/day)

EPC – exposure point concentration in biota tissue (milligrams per kilogram)

EF – exposure frequency (days/year)

ED – exposure duration (years)

IR – biota ingestion rate (mg/day)

BW – body weight (kg)

AT – averaging time (years)

The CDI is compared to toxicity values for oral exposures (detailed in Section 3.2) to evaluate hazards for each receptor group.

3.2 TOXICITY ASSESSMENT

A toxicity assessment identifies chemical-specific criteria that reflect the intrinsic toxicity of mercury and methyl mercury to humans. These toxicity criteria are used with estimates of exposure to estimate potential cancer risks and non-cancer hazards for receptors identified above. Because neither mercury nor methyl mercury is considered carcinogenic, only non-carcinogenic hazard was evaluated. Oral toxicity factors are used in the risk assessment for the ingestion pathway; dermal and inhalation exposure pathways are not complete for either receptor group.

For non-cancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular contaminant with the level of exposure that is considered protective — its reference dose (RfD). The RfD is an estimate of average daily dose to an individual that is likely to be without appreciable risk of harmful effects during a lifetime. The RfD is expressed in units of milligram chemical per kilogram body weight per day (mg/kg/day). The Oral RfD for methyl mercury (0.0001 mg/kg/day) was taken from the EPA Integrated Risk Information System database (EPA 2012). The oral RfD, uncertainty and modifying factors, and target organ for methyl mercury are presented in **Appendix A**.

3.3 HUMAN HEALTH RISK CHARACTERIZATION

The results of the exposure assessment and toxicity assessment were combined to calculate non-cancer health hazards for each receptor population. Non-cancer hazards were developed for methyl mercury using the percent of methyl mercury to total mercury presented in the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b).

The potential for non-cancer health hazards were calculated using the following equation:

$$HQ\ (unitless) = \frac{CDI\ (\frac{mg}{kg-day})}{RfD\ (\frac{mg}{kg-day})}$$

Where:

- HQ – Hazard quotient (unitless)
- CDI – Chronic daily intake averaged over the exposure duration (mg/kg/day)
- RfD – Oral RfD (mg/kg/day)

The ratio of exposure to toxicity is referred to as the hazard quotient (HQ). If a HQ exceeds the EPA target HQ of 1 (EPA 1989), the potential for non-cancer effects exists. Because the purposes of this risk reduction evaluation is to characterize the potential reduction of risk from the consumption of tissue by local residents through remedial activities. Hazards were not

summarized across species because risk from exposure to each biota species was evaluated individually.

Potential pre- and post-remediation non-cancer hazards for local consumers were calculated using this methodology. The results of the calculations are listed in **Tables 3-3** through **3-5** for the biota of concern (**Section 3.1.1.1**), and are summarized in **Table 3-6.** Note that for each biota, the remedial alternative with the highest estimated HQs (i.e., less protective) is MNR, while the remedial alternative with the lowest HQs (i.e., most protective) is dredging with a PRG of 300 ng/g. Furthermore, Alternative 1 (MNR) is not discussed below because it has the same potential for risk as the pre-remediation levels for all biota and exposure areas. Alternative 5 (Amendment Application) was also excluded from the risk reduction evaluation due to the level of unknowns associated with this alternative at this time (e.g., no estimate of SWAC reduction post application was quantified at this time).

3.3.1 Local Consumer

The following paragraphs discuss local consumer pre-remediation and post-remediation estimated HQs for all areas except the Southern Cove area, which is discussed separately in Section 3.4.

3.3.1.1 American Eel

Potential risks from the consumption of American eel by a local consumer are listed in **Table 3-3**, summarized in **Table 3-6**, and discussed in the sections below.

Pre-Remediation

For the local consumer, the pre-remediation methyl mercury HQs for the consumption of American eel tissue are above 1 for the freshwater area, Orrington, and the Orland River and East Channel for the food web and BSAF approaches. The risk levels for the BSAF approach was also above 1 for the Freshwater area (Bangor to Frankfort Flats).

Post-Remediation

For the local consumer, the post-remediation methyl mercury HQs for the consumption of American eel tissue for areas with a potential pre-remediation HQ greater than 1, the remedial alternatives that would result in a decrease of potential risk to acceptable levels are as follows (**Table 3-6**):

- Alternative 2: Enhanced MNR – When a PRG of 500 ng/g is assumed, the potential food web HQs decrease to a level of 1 or less for the Freshwater Area. Potential HQs remained near 1 for Orrington (1.2) and the Orland River and East Channel (1.1) when using the food web model. When using the BSAF approach, the potential HQs decrease to levels of 1 or less for all areas.

- Alternative 2: Enhanced MNR – When a PRG of 300 ng/g is assumed, the potential food web and BSAF approach HQs decrease to 1 or less for all areas and approaches.
- Alternative 3: Dredging – When a PRG of 500 ng/g or 300 ng/g is assumed, the potential food web and BSAF approach HQs decrease to 1 or less for all areas and approaches.

3.3.1.2 Black Duck

Potential risks from the consumption of black duck by a local consumer are listed in **Table 3-4**, summarized in **Table 3-6**, and discussed in the sections below.

Pre-Remediation

For the local consumer, the pre-remediation methyl mercury HQs for the consumption of black duck tissue are above 1 (ranging from 1.1 to 1.4) for the food web approach in all areas. When using the BSAF approach, potential HQs were below 1 for all areas.

Post-Remediation

For the local consumer, the potential post-remediation methyl mercury HQs for the consumption of black duck tissue for areas with a pre-remediation HQ greater than 1, the remedial alternatives that would result in a decrease of potential risk to acceptable levels are as follows (**Table 3-6**):

- Alternative 2: Enhanced MNR – When PRGs of 500 ng/g or 300 ng/g is assumed, potential HQs decrease to levels of 1 or less for all areas using the BSAF approach, but remained marginally above 1.0 for the food web approach.
- Alternative 3: Dredging – When PRGs of 500 ng/g or 300 ng/g is assumed, potential HQs decrease to levels below 1 for all areas and approaches.
- Alternative 4: Thin Layer Cap – Potential HQs for the whole river decrease to below 1 for the whole river and Mendall Marsh for both approaches.
- Alternative 6: Dredging and Thin Layer Cap – Potential HQs for the whole river decrease to below 1 for the whole river (BSAF approach) and Mendall Marsh (BSAF and food web approaches), but is marginally above 1.0 for the whole river when using the food web approach.

3.3.1.3 Lobster Consumption

Potential risks from the consumption of lobster by a local consumer are listed in **Table 3-5**, summarized in **Table 3-6**, and discussed in the sections below.

Pre-Remediation

For the local consumer, the pre-remediation methyl mercury HQs for the consumption of lobster tissue are below 1 for all exposure areas and approaches (including the use of both a median and an upper bound BSAF).

Post-Remediation

For the local consumer when using the upper bound BSAF, the potential post-remediation methyl mercury HQs for the consumption of lobster tissue are below 1 for all exposure areas and remedial alternatives when using the upper bound BSAF approach.

3.3.2 MeCDC Fish Tissue Action Level

The following paragraphs discuss local consumer pre-remediation and post-remediation tissue concentrations and how they compare to the MeCDC fish tissue action level of 200 ng/g methyl mercury for all areas except the Southern Cove area, which is discussed separately in Section 3.4.

3.3.2.1 American Eel

Concentrations of methyl mercury in American eel tissue are discussed below and presented in **Table 3-2** and summarized in **Table 3-7**.

Pre-Remediation

The pre-remediation methyl mercury concentrations, which range from 233 ng/g to 422 ng/g, are above the MeCDC fish tissue action level of 200 ng/g for the freshwater area, Bangor, Orrington, Frankford Flats, and the Orland River and East Channel for the food web and BSAF approaches.

Post-Remediation

The post-remediation methyl mercury tissue concentrations, the remedial alternatives that would result in a decrease concentration of methyl mercury in tissue to below the MeCDC fish tissue action level are as follows (**Table 3-7**):

- Alternative 2: Enhanced MNR – When a PRG of 500 ng/g is assumed, the tissue concentration of methyl mercury remains above the MeCDC fish tissue action level of 200 ng/g for all areas and approaches.
- Alternative 2: Enhanced MNR – When a PRG of 300 ng/g is assumed, the BSAF approach estimated concentration in eel tissue decreases to below the MeCDC fish tissue action level of 200 ng/g for all locations with the exception of Orrington with a methyl mercury concentration of 237 ng/g. For the food web approach, concentration of methyl mercury in eel tissue remain above the MeCDC fish tissue action level of 200 ng/g for all areas.
- Alternative 3: Dredging – When a PRG of 500 ng/g is assumed, the BSAF approach estimated concentration in eel tissue decreases to below the MeCDC fish tissue action level of 200 ng/g for all locations with the exception of Bangor and Orrington with tissue methyl mercury concentrations of 233 ng/g and 230 ng/g, respectively. For the food web approach, concentration of methyl mercury coin eel tissue remain above the MeCDC fish

tissue action level of 200 ng/g for all areas with the exception of the Orland River and East Channel, with a tissue methyl mercury concentration of 184 ng/g.

- Alternative 3: Dredging – When a PRG of 300 ng/g is assumed, the estimated fish tissue concentration decrease to levels below the MeCDC fish tissue action level of 200 ng/g for all areas and approaches.

3.3.2.2 Black Duck

Concentrations of methyl mercury in American eel tissue are discussed below and presented in **Table 3-2** and summarized in **Table 3-7**.

Pre-Remediation

The pre-remediation methyl mercury concentrations, which range from 234 ng/g to 700 ng/g, are above the MeCDC fish tissue action level of 200 ng/g for all areas and approaches.

Post-Remediation

The post-remediation methyl mercury tissue concentrations, the remedial alternatives that would result in a decrease concentration of methyl mercury in tissue to below the MeCDC fish tissue action level are as follows (**Table 3-7**):

- Alternative 2: Enhanced MNR – When a PRG of 500 ng/g or 300 ng/g is assumed, the concentrations of methyl mercury in tissue, which range from 221 ng/g to 563 ng/g, remains above the MeCDC fish tissue action level of 200 ng/g for all locations and approaches.
- Alternative 3: Dredging – When a PRG of 500 ng/g and 300 ng/g are assumed, the concentration of methyl mercury in tissue, which range from 67 ng/g to 480 ng/g, remains above the MeCDC fish tissue action level of 200 ng/g for the whole river (207 ng/g for a PRG of 500 ng/g and 202 ng/g for a PRG of 300 ng/g) and Mendall Marsh (480 ng/g) when using the food web approach and Mendall Marsh (234 ng/g) when using the BSAF approach. However, for both approaches the concentrations of methyl mercury in tissue for Verona East and the Orland River and East Channel decrease to below 200 ng/g (138 ng/g for the food web approach and 67 ng/g for the BSAF approach). Furthermore, when assuming the BSAF approach, the concentration of methyl mercury in tissue decreases to a range of 101 ng/g to 98 ng/g when assuming PRGs of 500 ng/g and 300 ng/g, respectively, for the whole river.
- Alternative 4: Thin Layer Cap – When assuming the food web approach, concentrations of methyl mercury in tissue, which range from 183 to 542 ng/g, remain above the MeCDC fish tissue action level for all areas and approaches, with the exception of Mendall Marsh when using the BSAF approach (183 ng/g).
- Alternative 6: Dredging and Thin Layer Cap – When assuming the food web approach, concentrations of methyl mercury in tissue, which range from 123 to 517 ng/g, remain

above the MeCDC fish tissue action level for all areas and approaches, with the exception of Mendall Marsh when using the BSAF approach (123 ng/g).

3.3.2.3 Lobster Consumption

Potential risks from the consumption of lobster by a local consumer are listed in **Table 3-5**, summarized in **Table 3-7**, and discussed in the sections below.

Pre-Remediation

The pre-remediation methyl mercury concentrations, which range from 172 ng/g to 182 ng/g, are below the MeCDC fish tissue action level of 200 ng/g for both the 2014 and 2016 lobster closure areas when using the food web approach. When using the BSAF approach, concentrations of methyl mercury are above the MeCDC fish tissue action levels for the 2014 lobster closure area (211 ng/g) and the 2014 and 2016 lobster closure area (250 ng/g and 237 ng/g, respectively). However, the tissue methyl mercury concentration in the 2016 lobster closure area of 200 ng/g is at the MeCDC fish tissue action level when using the BSAF approach.

Post-Remediation

The post-remediation methyl mercury tissue concentrations, the remedial alternatives that would result in a decrease concentration of methyl mercury in tissue to below the MeCDC fish tissue action level are as follows (**Table 3-7**):

- Alternative 2: Enhanced MNR – When a PRG of 500 ng/g is assumed, the concentration of methyl mercury concentration in tissue, which range from 171 ng/g (2014 closure area) to 200 ng/g (2016 closure area), remains below or equivalent to the MeCDC fish tissue action level of 200 ng/g for both approaches, but above 200 ng/g when using the upper bound BSAF approach (236 ng/g and 237 ng/g, respectively).
- Alternative 2: Enhanced MNR – When a PRG of 300 ng/g is assumed, the concentrations of methyl mercury in tissue, which range from 143 ng/g (2014 closure area) to 200 ng/g (2016 closure area), remains below or equivalent to the MeCDC fish tissue action level of 200 ng/g for both approaches, but the 2016 lobster closure area is above 200 ng/g when using the upper bound BSAF approach (237 ng/g) while the 2014 closure area remains below at 197 ng/g.
- Alternative 3: Dredging – When a PRG of 500 ng/g is assumed, the concentrations of methyl mercury concentration in tissue, which range from 172 ng/g (2016 closure area) to 201 ng/g (2014 closure area), remains below or approximately equivalent to the MeCDC fish tissue action level of 200 ng/g for both approaches, but above 200 ng/g when using the upper bound BSAF approach (237 ng/g and 238 ng/g, respectively).
- Alternative 3: Dredging – When a PRG of 300 ng/g is assumed, the concentrations of methyl mercury in tissue, which range from 121 ng/g (2014 closure area) to 200 ng/g (2016 closure area), remains below or equivalent to the MeCDC fish tissue action level of 200

ng/g for both approaches, but the 2016 lobster closure area is above 200 ng/g when using the upper bound BSAF approach (237 ng/g) while the 2014 closure area remains below at 166 ng/g.

3.4 RISK CHARACTERIZATION OF SOUTHERN COVE

Using the same methodology outlined above, risk from consumption of biota in the Southern Cove area (from BO-04 to OB-05 and full width of river) were developed. Remedial activities, including sediment dredging, were performed in Southern Cove in 2017 by Mallinckrodt. As detailed in the Corrective Measures Implementation Plan for Southern Cove (Anchor QEA and CDM Smith, Inc. 2017), a range of bathymetric, geotechnical, hydrodynamic, ecological, and geochemical data, including in situ characterization and characterization for material disposal following removal/dredging, were collected from 2015 to 2016. The overall design objectives for sediment removal in Southern Cove were to remove sediment where mercury concentrations exceed 2.2 mg/kg over a 0.25-acre area, as well as where specific locations (hot spots) of elevated mercury concentration were identified. Sediment dredged from Southern Cove can be characterized as solid, non-hazardous waste using the toxicity characteristic leaching procedure (Anchor QEA and CDM Smith, Inc. 2017). Details regarding the implementation of the Corrective Measures Plan have not been provided to Amec Foster Wheeler, and so are not available for inclusion in this report. Potential risks were calculated for pre-remediation, current post-remediation, and three of the remedial alternatives developed in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a). The results of the calculations are listed in **Tables 3-3** through **3-5** and summarized in **Table 3-6.**

3.4.1 Local Consumers

3.4.1.1 American Eel Consumption

Potential risks from the consumption of American eel by a local consumer are listed in **Table 3-3**, summarized in **Table 3-6**, and discussed in the sections below.

Pre-Remediation and Current Post-Remediation

For the local consumer, the pre-remediation methyl mercury HQs for the consumption of American eel tissue from Southern Cove are above 1 (ranging from 1.3 to 1.7). In addition, HQs associated with the current post-remediation sediment concentrations are also above 1 and remain almost unchanged based on Phase II and III datasets without post-remediation monitoring data considered for Southern Cove due to lack of availability when this *Risk Reduction Report* was published.

Post-Remediation

For the local consumer, the potential post-remediation methyl mercury HQs for the consumption of American eel tissue from Southern Cove decrease to levels below 1 with the exception of

Alternative 2: Enhanced MNR with a PRG of 300 ng/g or 500 ng/g remedial alternatives (**Table 3-6**).

3.4.1.2 Duck Consumption

Potential risks from the consumption of black duck by a local consumer are listed in **Table 3-4**, summarized in **Table 3-6**, and discussed in the sections below.

Pre-Remediation and Current Post-Remediation

For the local consumer, the pre-remediation methyl mercury HQs for the consumption of black duck tissue from Southern Cove are above 1 (ranging from 1.2 to 2.4). HQs associated with the current post-remediation sediment concentrations are also above 1, with an HQ range of 1.2 to 24, .and remain unchanged based on Phase II and III datasets without post-remediation monitoring data considered for Southern Cove because of unavailability. The current post-remediation sediment concentrations remain almost unchanged based on Phase II and III datasets without post-remediation monitoring data considered for Southern Cove because of unavailability of the post-remediation summary report when this *Risk Reduction Report* publication.

Post-Remediation

For the local consumer, the potential post-remediation methyl mercury HQs for the consumption of black duck tissue from Southern Cove decrease to a level below 1 for the following remedial alternatives (**Table 3-9**):

- Alternative 2: Enhanced MNR – When a PRG of 500 ng/g or 300 ng/g is assumed, the potential BSAF approach HQs decrease to a level below 1. The potential food web approach HQs remain above 1 with HQs ranging from 1.7 to 1.9.
- Alternative 3: Dredging – When a PRG of 500 ng/g or 300 ng/g is assumed, the potential HQs decrease to levels of below 1 when using the BSAF approach. The potential food web approach HQs remain above an HQ of 1 with both PRG approaches resulting in an HQs ranging from 1.5 to 1.6.

3.4.2 MeCDC Fish Tissue Action Level

3.4.2.1 American Eel (Representing Trophic Level 4 Fish) Consumption

Concentrations of methyl mercury in American eel tissue are discussed below and presented in **Table 3-2** and summarized in **Table 3-7**.

Pre-Remediation and Current Post-Remediation

The pre-remediation methyl mercury American eel tissue concentration (representing trophic level 4 fish) from Southern Cove are above the MeCDC fish tissue action level of 200 ng/g for both approaches (ranging from 397 to 511 ng/g).

Post-Remediation

The potential post-remediation methyl mercury American eel tissue concentrations (representing trophic level 4 fish) for Southern Cove remain above the MeCDC fish tissue action level of 200 ng/g for all locations and approaches, with the exception of Alternative 3: Dredging with a PRG of 300 ng/g remedial alternative (**Table 3-7**).

3.4.3 Duck Consumption

Potential risks from the consumption of American black duck by a local consumer are listed in **Table 3-4**, summarized in **Table 3-7**, and discussed in the sections below.

Pre-Remediation and Current Post-Remediation

The pre-remediation methyl mercury American black duck tissue concentration from Southern Cove are above the MeCDC fish tissue action level of 200 ng/g for both approaches (ranging from 600 to 1,234 ng/g).

Post-Remediation

The potential post-remediation methyl mercury American black duck tissue concentrations for Southern Cove remain above the MeCDC fish tissue action level of 200 ng/g for all locations and approaches, with the largest decrease in concentration for Alternative 3: Dredging with a PRG of 300 ng/g remedial alternative (**Table 3-7**), which would result in tissue concentrations of 650 ng/g and 316 ng/g for the food web and BSAF approaches, respectively.

4.0 PRE- AND POST-REMEDIATION ASSESSMENT OF ECOLOGICAL RISK

4.1 INTRODUCTION

This ecological risk reduction evaluation was based on the results of the Baseline Ecological Risk Assessment (BERA) presented in the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* report (Amec Foster Wheeler 2018b), which identified potential adverse risk to ecological receptors as a result of mercury exposure in the Estuary. The results of the BERA provide a point of reference for quantification of risk reduction that can be achieved by each remedial alternative considered in the *Alternatives Evaluation Report* (Amec Foster Wheeler 2018a).

4.2 RESULTS OF THE BERA

Multiple lines of evidence were used in the BERA to assess the potential for risk to representative receptors due to mercury exposure. Potential ecological exposure pathways evaluated in the BERA are summarized on **Figure 4-1** and **Figure 4-2**. **Figure 4-1** presents the conceptual exposure model, which presented on **Figure 4-2** illustrates the various trophic levels at the site.

Total mercury and/or methyl mercury concentrations in surface water, sediment, prey tissue, and receptor tissue were evaluated to characterize risk either through direct contact with surface water, food web exposure (i.e., dietary), and/or body burden (i.e., tissue accumulation). The tissue and dietary HQs calculated in the BERA are presented as **Tables 4-1** and **4-2**. The conclusions of the BERA are summarized as follows:

- ***Blue Mussels:*** There is no unacceptable risk for blue mussels based on surface water exposure. There is the potential for unacceptable risk for blue mussels based on total mercury tissue NOAEL-based HQs above 1.0. LOAEL-based HQs were equal to or below 1.0 for total both total or methyl mercury.
- ***American Lobster:*** There is no unacceptable risk for lobster based on lobster tail tissue body burdens.
- ***Forage Fish:*** There is no unacceptable risk for mummichog and rainbow smelt fish based on tissue body burdens or dietary exposure in the Estuary.
- ***Predatory Fish:*** There is the potential for unacceptable potential risk to Atlantic tomcod and American eel based on tissue total mercury and methyl mercury NOAEL HQs. However, unacceptable risk is unlikely because LOAEL HQs are below 1.0, which are based on a tissue mercury body burden for population effects for the LOAEL TRV. There is no unacceptable risk to predatory fish based on dietary exposure to mercury in the Estuary.
- ***Nelson's Sparrows and Red-Winged Blackbirds:*** There is the potential for unacceptable risk to marsh songbirds based on blood total mercury and methyl mercury NOAEL and LOAEL HQs above 1, as well as from dietary exposure to

mercury based on total mercury and methyl mercury NOAEL HQs equal to or above 1.0. However, the dietary LOAEL HQs for both Nelson's sparrow and red-winged blackbirds are below 1.0 for both total and methyl mercury.

- ***American Black Duck:*** There is the potential for unacceptable risk to the American black duck based on blood total mercury and methyl mercury NOAEL HQs above 1.0, as well as from dietary exposure to mercury based on a total mercury NOAEL HQ above 1.0. However, the LOAEL tissue and dietary HQs are below 1.0 for both total and methyl mercury.

- ***Piscivorous Birds:*** There is no unacceptable risk to piscivorous birds based on dietary exposure in the Estuary. Although blood mercury data for piscivorous birds indicates exceedances of the blood LOAEL TRV and egg mercury concentrations are elevated, these data are between 6 and 12 years old and might not be considered representative of current site conditions in the Estuary for making remedial decisions.

- ***Mink:*** There is no unacceptable risk to the mink based on dietary exposure to mercury in the Estuary.

Thus, there is the potential for unacceptable risk to several receptors because body burdens (i.e., blood concentrations) and/or dietary exposure NOAEL HQs are above 1.0. However, the only receptors with LOAEL HQs above 1.0 are the Nelson's sparrow and red-winged blackbird. When the NOAEL HQs are ≥ 1.0, but the LOAEL HQs are < 1.0, ecologically significant adverse effects to that receptor are possible as the threshold for effects is assumed to be between the NOAEL and LOAEL. There is uncertainty associated with defining the true toxicity threshold, so adverse effects are considered possible. A LOAEL-based HQ ≥ 1.0 indicates potential for adverse effects. There is potential for risk to marsh songbirds due to mercury exposure in the Estuary based on NOAEL and LOAEL HQs > 1.0.

4.2.1.1 Biota of Concern

Receptors included in the ecological risk reduction evaluation are only biota associated with potential adverse risk (i.e., LOAEL-based HQs above 1.0) based on the results of the BERA. The BERA indicates a potential for adverse risk to marsh songbirds (i.e., Nelson's sparrow and red-winged blackbird) due to exposure to mercury in the Estuary based on blood concentrations. One location for blue mussels had a tissue LOAEL-based HQ equal to 1.0; the remaining LOAEL-based HQs for the blue mussel were below 1.0. Therefore, blue mussels were not evaluated in the risk reduction because the current tissue body burden for blue mussels in that location resulted in an HQ equivalent to 1.0. Ecological receptors that were identified as not adversely impacted through exposure to mercury in the BERA are not included in the risk reduction evaluation. The ecological risk reduction evaluation focuses on the Nelson's sparrow and red-winged blackbird and the potential for adverse risk associated with body burden (i.e., mercury accumulation in blood).

4.3 ECOLOGICAL EXPOSURE ASSESSMENT

4.3.1 Exposure Areas

Ecological exposure for marsh songbirds was evaluated by area as follows:

- Mendall Marsh – West – includes marsh platform and intertidal sediments along the western portion of Mendall Marsh (i.e., along W-17-N and Mendall Marsh Southwest)
- Mendall Marsh – East – includes marsh platform and intertidal sediments along the eastern portion of Mendall Marsh (i.e., along Mendall Marsh Southeast)
- Southern Cove – includes marsh platform and intertidal sediments from BO-04 to OB-05 and the full width of the Penobscot River

4.3.2 Concentrations of Total Mercury in Tissue

For quantifying risk reduction, concentrations of total mercury in songbird blood were developed using the same approach used to calculate tissue concentrations for the human health risk reduction assessment presented in Section 3.1.3. Concentrations in songbird blood for the risk reduction were developed using two different approaches:

- Food web tissue-based approach; and
- BSAF tissue-based approach

Concentrations of total mercury in songbird blood were developed using site-specific and species-specific BSAFs and BAFs (i.e., predator-prey). The site-specific BSAFs and BAFs were developed as part of the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b) and are summarized in **Appendix A**. The models and calculated tissue concentrations are presented in **Appendix B**. The concentrations of total mercury in songbird blood calculated for the risk reduction evaluation are listed in **Table 4-3**.

4.4 ECOLOGICAL EFFECTS EVALUATION

Marsh songbird toxicity reference values (TRVs) used in the risk reduction evaluation were consistent with those used in the BERA. A NOAEL TRV of 210 ng/g and a LOAEL TRV of 2,100 ng/g were used as the blood TRVs for marsh songbirds based on reproduction. The blood LOAEL TRV of 2,100 ng/g is based on reproduction effects for the Carolina wren (*Thryothorus ludovicianus*; Jackson et al. 2011; Fuchsman et al. 2016). The NOAEL was calculated from the LOAEL by multiplying by 0.1, representative of a 10x uncertainty factor (EPA 1999). Refer to the BERA (Amec Foster Wheeler 2018b) for a detailed discussion on the TRVs.

4.5 ECOLOGICAL RISK CHARACTERIZATION

For the risk reduction evaluation, quantitative risk estimates or HQs were calculated by dividing the marsh songbird blood concentration by the blood TRV as shown in Equation 1:

Equation 1: $$HQ = \frac{Blood\ Mercury\ Concentration\ (\frac{ng}{g})}{Blood\ Mercury\ TRV\ \left(\frac{ng}{g}\right)}$$

HQs were calculated using pre- and post-remediation songbird blood concentrations for each remedial alternative and are listed in **Table 4-4**.

In interpreting HQ results, NOAEL-based HQs < 1 are considered to indicate no unacceptable potential risk. This determination is based on the compounded conservative assumptions used in the exposure model and the conservative nature of the NOAEL TRVs. Specifically, the NOAEL is a level at which no adverse effects have been observed in toxicity studies. Thus, when HQs based on NOAELs are < 1, the likelihood of adverse effects occurring at these concentrations is considered *de minimis* (negligible), and no unacceptable potential risk is expected. When the NOAEL HQs are ≥ 1, but the LOAEL HQs are < 1, ecologically significant adverse effects to that receptor are possible. Per EPA's ERAGS (1997), "The threshold for effects is assumed to be between the NOAEL and the LOAEL of a toxicity test". However, uncertainty is associated with defining the true toxicity threshold. Thus, while adverse effects are considered possible in this case, the results are reviewed also in the context of other lines of evidence and supporting information. A LOAEL-based HQ ≥ 1 indicates potential for adverse effects.

The following subsections discuss the results of the risk reduction characterization by area and receptor. Potential risks for Alternative 1: MNR are consistent with the potential risks estimated for pre-remediation conditions. Remedial activities including sediment dredging activities were performed in Southern Cove in 2017 by Mallinckrodt. The post-remediation summary report has not been published at this time so the values used to quantify risk reduction were those concentrations available in the project database when this *Risk Reduction Report* was generated. Potential risks for available data were calculated for pre-remediation, current post-remediation, and three of the remedial alternatives developed in the *Alternatives Evaluation Report* (Amec Foster Wheeler, 2018a).

4.5.1 Mendall Marsh

4.5.1.1 Nelson's Sparrow

Pre-Remediation

The pre-remediation NOAEL HQs for the Nelson's sparrow are greater than 1.0 (HQs of 11 to 19) for the food web approach and the BSAF approach for both Mendall Marsh areas (**Table 4-4**).

The pre-remediation LOAEL HQs are also greater than 1.0 (HQs of 1.1 to 1.9) for the food web and BSAF approaches.

Post-Remediation

The post-remediation NOAEL HQs for the Nelson's sparrow are above 1.0 for both Mendall Marsh areas and approaches for each remedial alternative evaluated (**Table 4-4**). The NOAEL HQs are consistently higher for the BSAF approach compared to the food web approach, and the HQs are relatively consistent across the different remedial alternatives evaluated with the lowest HQs associated with the dredging and thin-layer capping alternative. The post-remediation LOAEL HQs decrease to a value near or below 1.0 for Mendall Marsh for the following remedial alternatives (**Table 4-4**):

- Alternative 2: Enhanced MNR – When a PRG of 500 ng/g and 300 ng/g are assumed, the HQs marginally decrease to values near or at 1.0 (BSAF approach HQs of 1.6 to 1.8 and food web approach HQs of 1.0 or 1.1).
- Alternative 3: Dredging – When a PRG of 500 ng/g and 300 ng/g are assumed, the HQs for Mendall Marsh – West decrease to values below 1.0 (0.93 for food web approach) or near 1.0 (1.5 for BSAF approach). Mendall Marsh – East HQs remain consistent with pre-remediation HQs.
- Alternative 4: Thin-Layer Capping – The BSAF approach HQs decrease to values of 1.4 for Mendall Marsh – East and 1.5 for Mendall Marsh – West. The food web approach HQs decrease to values below 1.0 (0.90 for Mendall Marsh – East and 0.97 for Mendall Marsh – West).
- Alternative 6: Dredging and Thin-Layer Capping – The BSAF approach HQs decrease to values near or at 1.0 (1.3 for Mendall Marsh – West and 1.0 for Mendall Marsh – East). The food web approach HQs decrease to values below 1.0 (0.65 for Mendall Marsh – East and 0.78 for Mendall Marsh – West).

4.5.1.2 Red-Winged Blackbird

Pre-Remediation

The pre-remediation NOAEL HQs for the red-winged blackbird are above 1.0 (HQs of 13 to 19) for the food web approach and the BSAF approach for both Mendall Marsh areas (**Table 4-4**). The pre-remediation LOAEL HQs are also greater than 1.0 (HQs of 1.3 to 1.9) for the food web and BSAF approaches.

Post-Remediation

The post-remediation NOAEL HQs for the red-wing blackbird are above 1.0 for both Mendall Marsh areas and approaches for each remedial alternative evaluated (**Table 4-4**). The NOAEL

HQs are consistently higher for the food web approach compared to the BSAF approach, and the HQs are relatively consistent across the different remedial alternatives evaluated with the lowest HQs associated with the dredging and thin-layer capping alternative. The post-remediation LOAEL HQs decrease to values near or below 1.0 for Mendall Marsh for the following remedial alternatives (**Table 4-4**):

- Alternative 2: Enhanced MNR – When PRGs of 500 ng/g and 300 ng/g are assumed, the HQs marginally decrease to values near 1.0 (BSAF approach HQs of 1.2 to 1.3 and food web approach HQs of 1.6 or 1.8).
- Alternative 3: Dredging – When a PRG of 500 ng/g and 300 ng/g are assumed, the HQs for Mendall Marsh – West decrease to near 1.0 (1.5 for food web approach and 1.1 for BSAF approach). Mendall Marsh – East HQs remain consistent with pre-remediation HQs.
- Alternative 4: Thin-Layer Capping – The food web approach HQ decreases to values of 1.4 for Mendall Marsh – East and 1.5 for Mendall Marsh – West. The BSAF approach HQs decrease to values below near or at 1.0 (1.1 for Mendall Marsh – West and 1.0 for Mendall Marsh – East).
- Alternative 6: Dredging and Thin-Layer Capping – The food web approach HQs decrease to values near or at 1.0 (1.3 for Mendall Marsh – East and 1.0 for Mendall Marsh – West). The BSAF approach HQs decrease to values below 1.0 (0.75 for Mendall Marsh – East and 0.91 for Mendall Marsh – West).

4.5.2 Southern Cove

4.5.2.1 Nelson's Sparrow

Pre-Remediation and Current Post-Remediation

The pre-remediation NOAEL HQs (ranging from 29 to 46) and LOAEL HQs (ranging from 2.9 to 4.6) for the Nelson's sparrow are above 1.0 for the BSAF and food web approaches for Southern Cove (**Table 4-4**). Furthermore, the current post-remediation NOAEL and LOAEL HQs showed a slight decrease but overall were relatively consistent with the pre-remediation NOAEL and LOAEL HQs. As detailed in the Corrective Measures Implementation Plan for Southern Cove (Anchor QEA and CDM Smith, Inc. 2017), a range of bathymetric, geotechnical, hydrodynamic, ecological, and geochemical data, including in situ characterization and characterization for material disposal following removal/dredging, were collected from 2015 to 2016. The overall design objectives for sediment removal in Southern Cove were to remove sediment where mercury concentrations exceed 2.2 mg/kg over a 0.25-acre area, as well as where specific locations (hot spots) of elevated mercury concentration were identified. Sediment dredged from Southern Cove can be characterized as solid, non-hazardous waste using the toxicity characteristic leaching procedure (Anchor QEA and CDM Smith, Inc. 2017). Details regarding the implementation of the Corrective Measures Plan have not been provided to Amec Foster Wheeler, and so are not available for inclusion in this report.

Post-Remediation

The post-remediation NOAEL and LOAEL HQs for the Nelson's sparrow are above 1.0 for both approaches and each remedial alternative (**Table 4-4**). The NOAEL and LOAEL HQs are consistently higher for the BSAF approach compared to the food web approach. The post-remediation LOAEL HQs decrease to values near 1.0 for Southern Cove for the following remedial alternatives (**Table 4-4**):

- Alternative 2: Enhanced MNR – When PRGs of 500 ng/g and 300 ng/g are assumed, the food web approach HQs decrease to 1.9 and 1.7, respectively. BSAF approach HQs decreased to values of 2.7 to 3.0.
- Alternative 3: Dredging – When a PRG of 500 ng/g and 300 ng/g are assumed, the food web approach HQ decreases to 1.6 and 1.5, respectively. BSAF approach HQs decreased to values of 2.4 to 2.5.

4.5.2.2 Red-Winged Blackbird

Pre-Remediation and Current Post-Remediation

The pre-remediation NOAEL HQs (ranging from 33 to 46) and LOAEL HQs (ranging from 3.3 to 4.6) for the red-winged blackbird are above 1.0 for the BSAF and food web approaches for Southern Cove (**Table 4-4**). Furthermore, the current post-remediation NOAEL and LOAEL HQs were consistent with the pre-remediation NOAEL and LOAEL HQs. The current post-remediation sediment concentrations remain almost unchanged based on Phase II and III datasets without post-remediation monitoring data considered when at the time of this *Risk Reduction Report* was published.

Post-Remediation

The post-remediation NOAEL and LOAEL HQs for the red-winged blackbird are above 1.0 for both approaches and each remedial alternative (**Table 4-4**). The NOAEL and LOAEL HQs are consistently higher for the food web approach compared to the BSAF approach. The post-remediation LOAEL HQs decrease to values near 1.0 for Southern Cove for the following remedial alternatives (**Table 4-4**):

- Alternative 3: Dredging – When PRGs of 500 ng/g and 300 ng/g are assumed, the BSAF approach HQs decrease to 1.8. Food web approach HQs decreased to values of 2.4 to 2.5.

5.0 UNCERTAINTY

Measured sediment and biota tissue concentrations were used to estimate pre-remediation exposures for the risk reduction evaluation. Measured sediment and biota tissue data are not available to estimate potential post-remediation risks. Therefore, sediment and biota tissue concentrations used in the post-remediation risk calculations were estimated as discussed in Sections 3.1.3 and 4.3.2. Sources of uncertainty include how well the data used to estimate exposures pre- and post-remediation represents actual exposures, the assumptions used in the exposure parameters for the risk estimates, and the toxicity data used for effects levels. These levels of uncertainty are evaluated in the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b).

Uncertainties associated with the SWACs and estimated tissue concentrations used in the risk reduction evaluation are discussed below.

- Uncertainty Associated with Estimated Sediment Concentrations – Uncertainties associated with the SWACs calculated for each alternative are as follows:

  Pre-remediation/Alternative 1: MNR:
  - Concentrations for each AWAC used to generate the pre-remediation/Alternative 1: MNR SWACs are based on the samples collected in the reach/zone and the concentrations may vary depending on the hydrology within that reach (i.e., depositional vs. free-flowing environments). Thus, SWAC sediment concentrations may be over- or underestimated.
  - For reach/hydrodynamic zone units for which no field data were available for the 0– to 0.5–foot depth interval, an estimated bootstrap mean was assigned to the unit based on the bootstrap mean calculated for the nearest relevant hydrodynamic unit. For example, no data were available for the intertidal area on the west side of the Verona West reach. The Verona West Intertidal East hydrodynamic zone unit AWAC value of 92.2 ng/g was based on a single sample that did not appear to be representative of sediment concentrations in the vicinity based on sediment sample mercury concentrations and AWACs calculated from these samples. The nearest, relevant upstream intertidal hydrodynamic zone unit AWAC was used as a substitute value. The Bucksport Intertidal East hydrodynamic zone unit AWAC value was not deemed appropriate as a replacement because it is interrupted by the East Channel flowing around Verona Island. A bootstrap mean of 885.5 ng/g was assigned from the Bucksport Intertidal West zone, which is a relevant, upstream intertidal hydrodynamic zone unit. This may over- or underestimate the SWAC sediment concentrations.
  - SWACs depend on the designated reaches and hydrologically defined zones. Biota home ranges may extend outside the SWAC areas selected to represent each receptor. In some cases, SWACs represent of an area larger than the home range of a receptor (e.g., Mendall Marsh and red-winged blackbird), so the SWAC may over- or underestimate the exposure of a receptor to sediment.

Alternative 2: Enhanced MNR:

- There is uncertainty in the effect of redistribution of clean sediment on mercury sediment concentrations into the fringe or pocket marshes along the river and into Mendall Marsh.
- The change in mercury sediment concentrations in the mobile pool from this alternative depends on the mixing and redistribution of sediment throughout the system.

Alternative 3: Dredging:

- Concentrations of the SWACs may change differently than calculated due to the large areas and few samples characterizing the zones and the fringe and pocket marshes.
- There was no dredging change included for Mendall Marsh post-remediation SWACs. The only changes in the post-remediation calculations were in the W-17-N area due to the effect of dredging in this area. Thus, there is a SWAC change for the American black duck and marsh songbirds in Mendall Marsh due to the dredging proposed near W-17-N. The risk reduction calculated for Mendall Marsh under Alternative 3 uses these calculated post-dredging SWACs to estimate how potential risk levels may change based on the work upstream of Mendall Marsh.
- There is uncertainty in the effect of redistribution of clean sediment in the main stem of the river on mercury sediment concentrations transported into Mendall Marsh.
- System-wide remediation activities conducted outside of Mendall Marsh would improve conditions inside the marsh and that this concept is not included in the risk reduction calculations.

Alternative 4: Thin-Layer Capping

- Deposition of sediment from the Estuary may change the SWACs in Mendall Marsh or in the adjacent intertidal area with a potential change in mercury fate and transport.

Alternative 5: Amendment Application

- The potential reduction in mercury bioavailability and mercury concentration reduction is uncertain at this time. Thus, risk reduction was not performed for this alternative.

Alternative 6: Dredging in Intertidal and Subtidal Zones & Thin Layer Capping

- Deposition of sediment from the Estuary may change the SWACs in Mendall Marsh or in the adjacent intertidal area with a potential change in mercury fate and transport.
- Concentrations of the SWACs may change differently than calculated due to the large areas and limited number of samples characterizing the zones.

- Uncertainty Associated with Estimated Biota Tissue Concentrations - The estimated biota tissue concentrations used in the pre-remediation and post-remediation risk calculations were developed using site-specific and species-specific BSAFs and BAFs (i.e., predator-prey), as discussed in Section 3.1.3. The site-specific BSAFs and BAFs were developed

as part of the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b). The assumptions and uncertainties underlying the development of these BSAFs and BAFs are discussed in Amec Foster Wheeler (2018b). Application of a site-wide BSAF or BAF may over- or underestimate uptake by receptors throughout various areas within the Estuary. In addition, the estimated concentrations of methyl mercury tissue differ from the measured concentrations reported in tissue and presented in the *Penobscot River Risk Assessment and Preliminary Remediation Goal Development* (Amec Foster Wheeler 2018b). This is due to the fact that the modeled concentrations are based over larger exposure areas than the measured tissue concentrations, which were location-specific within the Estuary. Furthermore, biota are mobile and can be exposed to multiple areas within the Estuary during their lifetimes, resulting in differing levels of exposure. As such, the use of food web and BSAF models are acceptable methods to derive modeled biotic tissue concentrations. The purpose of the risk reduction report is to show the overall potential for decreases in total mercury sediment concentrations for which the use of modeled tissue concentrations are appropriate.

6.0 SUMMARY AND CONCLUSIONS

The remedial alternatives that would result in a decrease of potential human health and ecological risks to HQs below 1.0 is summarized in **Table 6-1** and below. The percent decrease in risk for each remedial alternative is summarized in **Table 6-2** and below.

6.1 MAIN CHANNEL OF THE PENOBSCOT RIVER AND THE ORLAND RIVER

The results of the human health risk reduction evaluation for the main channel of the Penobscot River and the Orland River indicated that a decrease in levels of potential risk depended on the species and the remedial alternative. The receptor-specific results of the evaluation are as follows:

Local Consumers

- Potential risks from the consumption of American eel (representing trophic level 4 fish species) by local consumers – For local consumers, Alternative 2: Enhanced MNR (PRG of 300 ng/g) and Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) would result in a decrease in potential risk to acceptable levels. Alternative 2: Enhanced MNR (PRG of 500 ng/g) would result in potential risk levels near 1 (HQs ranging from 1.2 to below 1).
- Potential risks from the consumption of American black duck by local consumers – The remedial alternative that would result in a decrease in potential risk to acceptable levels is Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g). Alternative 2: Enhanced MNR (PRG of 500 ng/g and 300 ng/g) would result in potential risk levels near 1 (HQs ranging from 1.3 to below 1).
- Potential risks from the consumption of lobster by local consumers – Because pre-remediation risks for both the 2014 and 2016 closure areas were below acceptable levels and lobster is an important economic resource for the State of Maine, a more conservative risk reduction approach was undertaken for lobster consumption using an upper-bound BSAF. Under this more conservative risk reduction approach (using the upper bound BSAF), no remedial action is needed to meet acceptable risk levels for the lobster based on the local consumer consumption rates.

MeCDC Fish Tissue Action Level

- Concentration of methyl mercury in American eel tissue (representing trophic level 4 fish species) – Alternative 3: Dredging (PRG of 300 ng/g) would result in a decrease of tissue concentrations to below the MeCDC fish tissue action level of 200 ng/g.
- Concentration of methyl mercury in American black duck tissue – Alternative 3: Dredging (PRG of 300 ng/g) would result in a decrease of tissue concentrations to at or below the MeCDC fish tissue action level of 200 ng/g when assuming the BSAF approach.
- Concentration of methyl mercury in American lobster tissue – Because pre-remediation risks for both the 2014 and 2016 closure areas were below acceptable levels and lobster is an important economic resource for the State of Maine, a more conservative risk

reduction approach was undertaken for lobster consumption using an upper-bound BSAF. Under this more conservative risk reduction approach (using the upper bound BSAF), Alternative 2: Enhanced MNR (PRG of 300 ng/g) and Alternative 3: Dredging (PRG of 300 ng/g) would result in a decrease to below 200 ng/g, with the exception of the 2016 lobster closure area when assuming the upper bound BSAF.

For each remedial alternative, the percent decrease in potential risk was developed and summarized in **Table 6-2**. For the main channel of the Penobscot River and the Orland River, the percent decrease in potential risk for each remedial alternative is as follows:

- Alternative 1: MNR – No change for this alternative because potential risks are the same as the pre-remediation levels.
- Alternative 2: Enhanced MNR – Potential risks decreased by 5.8 to 20 percent (PRG of 500 ng/g) and by 21 to 31 percent (PRG of 300 ng/g) depending on the receptor and exposure areas.
- Alternative 3: Dredging – Depending on the receptor and exposure areas, potential risks decreased from 0 to 80 percent (PRG of 500 ng/g) and by 34 to 80 percent (PRG of 300 ng/g).

Based on the risk reduction evaluation for the main channel of the Penobscot River and the Orland River, the remedial alternatives that would result in potential human health risk levels near or below 1.0 for the above receptors, with the exception of the American black duck based on the food web approach, are:

- Alternative 2: Enhanced MNR (PRG of 300 ng/g)
- Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g).

Based on the risk reduction evaluation for the main channel of the Penobscot River and the Orland River, the remedial alternatives that would result in methyl mercury tissue concentrations below 200 ng/g for the above receptors, with the exception of the American black duck based on the food web approach and the American lobster using the upper bound BSAF, are:

- Alternative 2: Enhanced MNR (PRG of 300 ng/g)
- Alternative 3: Dredging (PRG of 300 ng/g).

Alternative 3: Dredging (PRG of 300 ng/g) would result in the lowest potential human health risks from the consumption of American eel (representing trophic level 4 fish species), American black duck, and American lobster by local consumers, as well as, the lowest concentrations of methyl mercury in biota tissue.

6.2 MENDALL MARSH

The results of the human health and ecological risk reduction evaluation for Mendall Marsh indicated that a decrease in levels of potential risk depended on the species and the remedial alternative. The receptor-specific results of the evaluation are as follows:

Local Consumers

- Potential risks from the consumption of American black duck by local consumers – The BSAF approach risk level for black duck has an HQ less than 1.0. The food chain black duck risk has an HQ greater than 1.0. The remedial alternatives that would result in a decrease in potential food chain risk to acceptable levels for Mendall Marsh are Alternative 4: Thin-layer capping and Alternative 6: Dredging and thin-layer capping.

MeCDC Fish Tissue Action Level

- Concentration of methyl mercury in American black duck tissue – The remedial alternatives that would result in a decrease in methyl mercury tissue concentration to below 200 ng/g for Mendall Marsh are Alternative 4: Thin-layer capping (BSAF approach only) and Alternative 6: Dredging and thin-layer capping (BSAF approach only).

Ecological Receptors

- Potential ecological risks for the Nelson's sparrow and red-winged blackbird – The remedial alternative that would result in a decrease in potential LOAEL risk levels below 1.0 for Mendall Marsh – West and Mendall Marsh – East is Alternative 6: Dredging and thin-layer capping. The additional remedial alternatives which would result in reduction of potential risk levels to near 1.0 (HQs ranging from 1.5 to below 1.0) are Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) for Mendall Marsh - West and Alternative 4: Thin-layer capping for both Mendall Marsh – East and West.

For each remedial alternative, the percent decrease in potential risk was developed and summarized in **Table 6-2**. For Mendall Marsh, the percent decrease in potential risk for each remedial alternative are as follows:

- Alternative 1: MNR – No change for this alternative because potential risks are the same as the pre-remediation levels.
- Alternative 2: Enhanced MNR – Potential risks decreased by 4.1 to 5.1 percent (PRG of 500 ng/g) and by 8.7 to 10 percent (PRG of 300 ng/g), depending on the receptor and exposure areas.
- Alternative 3: Dredging – Potential risks decreased from 0 to 21 percent (PRG of 500 ng/g) and by 0 to 58 percent (PRG of 300 ng/g), depending on the receptor and exposure areas.
- Alternative 4: Thin-Layer Capping – Potential risks decreased from 18 to 22 percent, depending on the receptor and exposure areas.
- Alternative 6: Dredging and Thin-Layer Capping – Potential risks decreased from 33 to 47 percent, depending on the receptor and exposure areas.

Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g), Alternative 4: Thin-layer capping, and Alternative 6: Dredging and thin-layer capping would result in potential ecological risk levels near or below 1.0 for marsh songbirds. Based on the risk reduction evaluation, the remedial

alternatives that would result in potential human health risk levels at or below 1.0, as well as, tissue concentrations below 200 ng/g (with the exception of the American black duck using the food web approach), for Mendall Marsh include 4: Thin-layer capping and Alternative 6: Dredging and thin-layer capping.

6.3 SOUTHERN COVE

The results of the human health and ecological risk reduction evaluation for Southern Cove indicated that a decrease in levels of potential risk depend on the species and the remedial alternative. The receptor-specific results of the evaluation are as follows:

Local Consumers

- Potential risks from the consumption of American eel (representing trophic level 4 fish species) by local consumers – For local consumers, Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) would result in potential risk levels below 1.0 in Southern Cove. Alternative 2: Enhanced MNR (PRG of 300 ng/g) would result in potential risk levels near 1 (HQs ranging from 0.88 to 1.3).
- Potential risks from the consumption of American black duck by local consumers – No remedial alternatives based on the food web approach would result in potential risk levels below 1.0 in Southern Cove. Alternative 3: Dredging (PRGs of 500 ng/g and 300 ng/g) would result in the lowest potential risk levels for local consumers (HQs ranging from 0.75 to 1.6), while Alternative 2: Enhanced MNR (PRGs of 500 ng/g and 300 ng/g) would result in a slightly higher risk (HQs ranging from 0.84 to 1.9) for the BSAF and food web approaches.

MeCDC Fish Tissue Action Level

- Concentration of methyl mercury in American eel tissue (representing trophic level 4 fish species) – Alternative 3: Dredging (PRG of 300 ng/g) would result in methyl mercury tissue concentrations below 200 ng/g for the American eel.
- Concentration of methyl mercury in American black duck tissue – None of the remedial alternatives would result in a decrease in methyl mercury tissue concentration to below 200 ng/g for Southern Cove. However, Alternative 3: Dredging (PRG of 300 ng/g) would result in the lowest potential tissue concentrations.

Ecological Receptors

- Potential ecological risks for the Nelson's sparrow – No remedial alternatives would result in potential risk levels below 1.0 in Southern Cove. The remedial alternative that would result in the lowest LOAEL HQs is Alternative 3: Dredging with a PRG of 300 ng/g, which would result in a range of HQs from 1.5 to 2.5.
- Potential ecological risks for the red-winged blackbird – No remedial alternatives would result in potential risk levels below 1.0 in Southern Cove. The remedial alternative that

would result in the lowest LOAEL HQs is Alternative 3: Dredging with a PRG of 300 ng/g, which would result in a range of HQs from 1.8 to 2.5.

For each remedial alternative, the percent decrease in potential risk was developed and summarized in **Table 6-2**. For Southern Cove, the percent decrease in potential risk for each remedial alternative is as follows:

- Alternative 1: MNR – No change for this alternative because potential risks are the same as the current post-remediation levels.
- Alternative 2: Enhanced MNR – Potential risks decreased from 23 to 35 percent (PRG of 500 ng/g) and by 34 to 41 percent (PRG of 300 ng/g), depending on the receptor and exposure areas.
- Alternative 3: Dredging – Potential risks decreased from 42 to 46 percent (PRG of 500 ng/g) and by 47 to 80 percent (PRG of 300 ng/g), depending on the receptor and exposure areas.

Based on the risk reduction evaluation, the remedial alternative that would result in the lowest potential human health and ecological risk levels near or below 1.0 and methyl mercury tissue concentrations close to 200 ng/g for Southern Cove receptors is Alternative 3: Dredging with a PRG of 300 ng/g.

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TABLES

TABLE 2-1

PRE- AND POST-REMEDIATION SURFACE WEIGHTED AVERAGE CONCENTRATIONS OF TOTAL MERCURY
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Location	Pre-Remediation Concentration (ng/g)	Current Post-Remediation Concentration (ng/g)	Post-Remediation Concentration (ng/g)						
			Alternative 1: MNR	Alternative 2: Enhanced MNR		Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal)		Alternative 4: Thin Layer Cap	Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Cap
				PRG = 500 ng/g	PRG = 300 ng/g	PRG = 500 ng/g	PRG = 300 ng/g	PRG = 500 ng/g	PRG = 300 ng/g
American Lobster									
2014 Lobster Closure Area	507	--	NC	478	399	482	337	--	--
2016 Lobster Closure Area	480	--	NC	NC	NC	NC	NC	--	--
American Eel									
Freshwater Area (Bangor to Frankfort Flats)	618	--	NC	537	459	463	205	--	--
Bangor	544	--	NC	512	421	544	189	--	--
Orrington	809	--	NC	655	555	538	185	--	--
Frankfort Flats	535	--	NC	476	417	406	233	--	--
Orland River and East Channel	766	--	NC	621	533	334	334	--	--
Southern Cove	927	923	NC	711	611	540	182	--	--
American Black Duck									
Whole River	735	--	NC	629	574	271	264	708	676
Mendall Marsh	628	--	NC	596	596	628	628	492	331
Verona East	819	--	NC	679	594	180	180	--	--
Orland River and East Channel	915	--	NC	736	649	180	180	--	--
Southern Cove	1,612	1,602	NC	1,051	951	878	849	--	--
Nelson's Sparrow									
Mendall Marsh - West	656	--	NC	622	587	519	519	540	438
Mendall Marsh - East	622	--	NC	597	568	622	622	502	361
Southern Cove	1,612	1,602	NC	1,051	951	878	849	--	--
Red-Winged Blackbird									
Mendall Marsh - West	656	--	NC	622	587	519	519	540	438
Mendall Marsh - East	622	--	NC	597	568	622	622	502	361
Southern Cove	1,612	1,602	NC	1,051	951	878	849	--	--

Abbreviations:
ng/g = nanograms per gram
NA = not applicable
NC = No change from Pre-Remedial Concentration
-- = Not Calculated

Prepared by: IMR 08/28/18
Checked by: NSR 08/29/18

TABLE 3-1

METHYL MERCURY RISKS BY SAMPLING LOCATION FROM THE HUMAN HEALTH RISK ASSESSMENT
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area	Methyl Mercury EPC (ng/g)	Younger Child Local Consumer Methyl Mercury HQ
Trophic Level 3 Shellfish		
American Lobster		
Frenchman Bay - Reference	40.7	0.01
2014 Closure	436	0.1
2016 Closure	234	0.06
Odom Ledge	481	0.1
South Verona	398	0.1
Cape Jellison	263	0.07
Turner Point	224	0.06
Harborside	104	0.03
Trophic Level 2 Shellfish		
Blue Mussel		
Frenchman Bay - Reference	3.91	0.0008
ES15	29.6	0.006
ES13	35.9	0.007
ES03	42.6	0.008
Fort Point	37.8	0.007
Trophic Level 3 Finfish		
Rainbow Smelt		
Frenchman Bay - Reference	9.03	0.03
OB5	140	0.4
OB4	56.1	0.2
OB1	58.1	0.2
ES13	40.2	0.1
Fort Point	66.8	0.2
Atlantic Tomcod		
Frenchman Bay - Reference	29.2	0.09
BO4	191	0.6
OB5	145	0.4
OB1	166	0.5
ES13	108	0.3
Fort Point	59.4	0.2
Trophic Level 4 Finfish		
American Eel		
OV4 - Reference	282	0.9
BO4	613	**2**
OB5	331	1
OB1	347	1
Trophic Level 3 Waterfowl		
American Black Duck		
Frenchman Bay - Reference	68.2	0.1
Mendall Marsh	343	0.7
ES-13	310	0.7

Notes:

1. Yellow highlighting and bold text signifies that the reported HQ is above the target HQ of 1.0

Abbreviations:

-- = Hazard quotients were not developed for this receptor
EPC = exposure point concentration
HQ = hazard quotient
UCL = upper confidence limit
ng/g = nanograms per gram

Prepared by: IMR 08/22/18
Checked by: LMS 08/27/18

TABLE 3-2

CONCENTRATIONS OF TOTAL MERCURY IN BIOTA TISSUE FOR HUMAN HEALTH RISK RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Location	Analyte	Media	Percentage of Total Mercury[1]	Pre-Remediation (ng/g)		Current Post-Remediation (ng/g)		Post Remediation Alternative 1: MNR		Post Remediation Alternative 2: Enhanced MNR PRG = 500 ng/g		Post Remediation Alternative 2: Enhanced MNR PRG = 300 ng/g	
				Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach
American Lobster													
2014 Lobster Closure Area	Methyl Mercury	Tail tissue	**92%**	**182**	**211**	**--**	**--**	**182**	**211**	**171**	**199**	**143**	**166**
	Total Mercury	Tail tissue	**NA**	**197**	**228**	**--**	**--**	**197**	**228**	**185**	**215**	**155**	**180**
2016 Lobster Closure Area	Methyl Mercury	Tail tissue	**92%**	**172**	**200**	**--**	**--**	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**
	Total Mercury	Tail tissue	**NA**	**186**	**216**	**--**	**--**	**NC**	**NC**	**NC**	**NC**	**NC**	**NC**
2014 Lobster Closure Area - Upper Bound BSAF	Methyl Mercury	Tail tissue	**92%**	**--**	**250**	**--**	**--**	**--**	**250**	**--**	**236**	**--**	**197**
	Total Mercury	Tail tissue	**NA**	**--**	**270**	**--**	**--**	**--**	**270**	**--**	**255**	**--**	**213**
2016 Lobster Closure Area - Upper Bound BSAF	Methyl Mercury	Tail tissue	**92%**	**--**	**237**	**--**	**--**	**--**	**NC**	**--**	**NC**	**--**	**NC**
	Total Mercury	Tail tissue	**NA**	**--**	**256**	**--**	**--**	**--**	**NC**	**--**	**NC**	**--**	**NC**
American Eel													
Freshwater Area (Bangor to Frankfort Flats)	Methyl Mercury	Whole body tissue	88%	340	264	--	--	340	264	296	230	253	196
	Total Mercury	Whole body tissue	NA	388	302	--	--	388	302	338	262	288	224
Bangor	Methyl Mercury	Whole body tissue	88%	300	233	--	--	300	233	282	219	232	180
	Total Mercury	Whole body tissue	NA	342	266	--	--	342	266	322	250	265	206
Orrington	Methyl Mercury	Whole body tissue	88%	446	346	--	--	446	346	361	280	306	237
	Total Mercury	Whole body tissue	NA	509	395	--	--	509	395	412	320	349	271
Frankfort Flats	Methyl Mercury	Whole body tissue	88%	295	229	--	--	295	229	262	204	230	179
	Total Mercury	Whole body tissue	NA	336	261	--	--	336	261	299	232	262	204
Orland River and East Channel	Methyl Mercury	Whole body tissue	88%	422	328	--	--	422	328	342	266	294	228
	Total Mercury	Whole body tissue	NA	482	374	--	--	482	374	390	303	335	260
Southern Cove	Methyl Mercury	Whole body tissue	88%	511	397	509	395	509	395	392	304	337	262
	Total Mercury	Whole body tissue	NA	583	453	580	451	580	451	447	347	384	299
American Black Duck													
Whole River	Methyl Mercury	Muscle tissue	98%	563	274	--	--	563	274	481	234	439	214
	Total Mercury	Muscle tissue	NA	576	280	--	--	576	280	493	240	450	219
Mendall Marsh	Methyl Mercury	Muscle tissue	98%	480	234	--	--	480	234	456	222	456	222
	Total Mercury	Muscle tissue	NA	492	239	--	--	492	239	467	227	467	227
Verona East	Methyl Mercury	Muscle tissue	98%	627	305	--	--	627	305	520	253	455	221
	Total Mercury	Muscle tissue	NA	641	312	--	--	641	312	532	259	465	226
Orland River and East Channel	Methyl Mercury	Muscle tissue	98%	700	341	--	--	700	341	563	274	497	242
	Total Mercury	Muscle tissue	NA	717	349	--	--	717	349	576	280	508	247
Southern Cove	Methyl Mercury	Muscle tissue	98%	1,234	600	1,226	596	1,226	596	804	391	728	354
	Total Mercury	Muscle tissue	NA	1,262	614	1,254	610	1,254	610	823	400	745	362

Abbreviations:
ng/g = nanograms per gram
NA = not applicable
NC = No change from Pre-Remedial Concentration
-- = Not Calculated

TABLE 3-2

CONCENTRATIONS OF TOTAL MERCURY IN BIOTA TISSUE FOR HUMAN HEALTH RISK
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Location	Analyte	Media	Percentage of Total Mercury[1]	Post Remediation							
				Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal)				Alternative 4: Thin Layer Cap		Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Cap	
				PRG = 500 ng/g		PRG = 300 ng/g					
				Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach
American Lobster											
2014 Lobster Closure Area	Methyl Mercury	Tail tissue	**92%**	**173**	**201**	**121**	**140**	--	--	--	--
	Total Mercury	Tail tissue	**NA**	**187**	**217**	**131**	**152**	--	--	--	--
2016 Lobster Closure Area	Methyl Mercury	Tail tissue	**92%**	**NC**	**NC**	**NC**	**NC**	--	--	--	--
	Total Mercury	Tail tissue	**NA**	**NC**	**NC**	**NC**	**NC**	--	--	--	--
2014 Lobster Closure Area - Upper Bound BSAF	Methyl Mercury	Tail tissue	**92%**	**--**	**238**	**--**	**166**	--	--	--	--
	Total Mercury	Tail tissue	**NA**	**--**	**257**	**--**	**179**	--	--	--	--
2016 Lobster Closure Area - Upper Bound BSAF	Methyl Mercury	Tail tissue	**92%**	**--**	**NC**	**--**	**NC**	--	--	--	--
	Total Mercury	Tail tissue	**NA**	**--**	**NC**	**--**	**NC**	--	--	--	--
American Eel											
Freshwater Area (Bangor to Frankfort Flats)	Methyl Mercury	Whole body tissue	88%	255	198	113	88	--	--	--	--
	Total Mercury	Whole body tissue	NA	291	226	129	100	--	--	--	--
Bangor	Methyl Mercury	Whole body tissue	88%	300	233	104	81	--	--	--	--
	Total Mercury	Whole body tissue	NA	342	266	119	92	--	--	--	--
Orrington	Methyl Mercury	Whole body tissue	88%	297	230	102	79	--	--	--	--
	Total Mercury	Whole body tissue	NA	338	263	116	90	--	--	--	--
Frankfort Flats	Methyl Mercury	Whole body tissue	88%	224	174	128	100	--	--	--	--
	Total Mercury	Whole body tissue	NA	255	198	146	114	--	--	--	--
Orland River and East Channel	Methyl Mercury	Whole body tissue	88%	184	143	184	143	--	--	--	--
	Total Mercury	Whole body tissue	NA	210	163	210	163	--	--	--	--
Southern Cove	Methyl Mercury	Whole body tissue	88%	298	231	100	78	--	--	--	--
	Total Mercury	Whole body tissue	NA	340	264	114	89	--	--	--	--
American Black Duck											
Whole River	Methyl Mercury	Muscle tissue	98%	207	101	202	98	542	264	517	252
	Total Mercury	Muscle tissue	NA	212	103	207	101	554	270	529	258
Mendall Marsh	Methyl Mercury	Muscle tissue	98%	480	234	480	234	377	183	254	123
	Total Mercury	Muscle tissue	NA	492	239	492	239	386	188	259	126
Verona East	Methyl Mercury	Muscle tissue	98%	138	67	138	67	--	--	--	--
	Total Mercury	Muscle tissue	NA	141	69	141	69	--	--	--	--
Orland River and East Channel	Methyl Mercury	Muscle tissue	98%	138	67	138	67	--	--	--	--
	Total Mercury	Muscle tissue	NA	141	69	141	69	--	--	--	--
Southern Cove	Methyl Mercury	Muscle tissue	98%	672	327	650	316	--	--	--	--
	Total Mercury	Muscle tissue	NA	687	334	665	324	--	--	--	--

Abbreviations:
ng/g = nanograms per gram
NA = not applicable
NC = No change from Pre-Remedial Concentration
-- = Not Calculated

Prepared by: IMR 08/22/18
Checked by: LMS 08/27/18

TABLE 3-3

RISK CHARACTERIZATION - AMERICAN EEL, LOCAL CONSUMER
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area	Oral Reference Dose (mg/kg/day)	Food Web Approach			BSAF Approach		
		Exposure Point Concentration - Food Web Approach (mg/kg)	Chronic Daily Intake[2] (mg/kg/day)	HQ[3]	Exposure Point Concentration (mg/kg)	Chronic Daily Intake[2] (mg/kg/day)	HQ[3]
Child Local Consumer							
Pre-Remediation							
Freshwater Area (Bangor to Frankfort Flats)	1.0E-04	0.340	1.1E-04	**1.1**	0.264	8.9E-05	0.89
Bangor	1.0E-04	0.300	1.0E-04	1.0	0.233	7.8E-05	0.78
Orrington	1.0E-04	0.446	1.5E-04	**1.5**	0.346	1.2E-04	**1.2**
Frankfort Flats	1.0E-04	0.295	9.9E-05	0.99	0.229	7.7E-05	0.77
Orland River and East Channel	1.0E-04	0.422	1.4E-04	**1.4**	0.328	1.1E-04	**1.1**
Southern Cove	1.0E-04	0.511	1.7E-04	**1.7**	0.397	1.3E-04	**1.3**
Current Post-Remediation							
Southern Cove	1.0E-04	0.509	1.7E-04	**1.7**	0.395	1.3E-04	**1.3**
Post-Remediation							
Alternative 1: MNR							
Freshwater Area (Bangor to Frankfort Flats)	1.0E-04	0.340	1.1E-04	**1.1**	0.264	8.9E-05	0.89
Bangor	1.0E-04	0.300	1.0E-04	1.0	0.233	7.8E-05	0.78
Orrington	1.0E-04	0.446	1.5E-04	**1.5**	0.346	1.2E-04	**1.2**
Frankfort Flats	1.0E-04	0.295	9.9E-05	1.0	0.229	7.7E-05	0.77
Orland River and East Channel	1.0E-04	0.422	1.4E-04	**1.4**	0.328	1.1E-04	**1.1**
Southern Cove	1.0E-04	0.509	1.7E-04	**1.7**	0.395	1.3E-04	**1.3**
Alternative 2: Enhanced MNR, PRG = 500 ng/g							
Freshwater Area (Bangor to Frankfort Flats)	1.0E-04	0.296	9.9E-05	0.99	0.230	7.7E-05	0.77
Bangor	1.0E-04	0.282	9.5E-05	0.95	0.219	7.3E-05	0.73
Orrington	1.0E-04	0.361	1.2E-04	**1.2**	0.280	9.4E-05	0.94
Frankfort Flats	1.0E-04	0.262	8.8E-05	0.88	0.204	6.8E-05	0.68
Orland River and East Channel	1.0E-04	0.342	1.1E-04	**1.1**	0.266	8.9E-05	0.89
Southern Cove	1.0E-04	0.392	1.3E-04	**1.3**	0.304	1.0E-04	1.0
Alternative 2: Enhanced MNR, PRG = 300 ng/g							
Freshwater Area (Bangor to Frankfort Flats)	1.0E-04	0.253	8.5E-05	0.85	0.196	6.6E-05	0.66
Bangor	1.0E-04	0.232	7.8E-05	0.78	0.180	6.0E-05	0.60
Orrington	1.0E-04	0.306	1.0E-04	1.0	0.237	8.0E-05	0.80
Frankfort Flats	1.0E-04	0.230	7.7E-05	0.77	0.179	6.0E-05	0.60
Orland River and East Channel	1.0E-04	0.294	9.8E-05	0.98	0.228	7.6E-05	0.76
Southern Cove	1.0E-04	0.337	1.1E-04	**1.1**	0.262	8.8E-05	0.88
Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal), PRG = 500 ng/g							
Freshwater Area (Bangor to Frankfort Flats)	1.0E-04	0.255	8.5E-05	0.85	0.198	6.6E-05	0.66
Bangor	1.0E-04	0.300	1.0E-04	1.0	0.233	7.8E-05	0.78
Orrington	1.0E-04	0.297	9.9E-05	0.99	0.230	7.7E-05	0.77
Frankfort Flats	1.0E-04	0.224	7.5E-05	0.75	0.174	5.8E-05	0.58
Orland River and East Channel	1.0E-04	0.184	6.2E-05	0.62	0.143	4.8E-05	0.48
Southern Cove	1.0E-04	0.298	1.0E-04	1.0	0.231	7.7E-05	0.77
Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal), PRG = 300 ng/g							
Freshwater Area (Bangor to Frankfort Flats)	1.0E-04	0.113	3.8E-05	0.38	0.088	2.9E-05	0.29
Bangor	1.0E-04	0.104	3.5E-05	0.35	0.081	2.7E-05	0.27
Orrington	1.0E-04	0.102	3.4E-05	0.34	0.079	2.6E-05	0.26
Frankfort Flats	1.0E-04	0.128	4.3E-05	0.43	0.100	3.3E-05	0.33
Orland River and East Channel	1.0E-04	0.184	6.2E-05	0.62	0.143	4.8E-05	0.48
Southern Cove	1.0E-04	0.100	3.4E-05	0.34	0.0779	2.6E-05	0.26

Notes:

1. Yellow highlighting and bold text signifies that the reported HQ is above than the target HQ of 1.0
2. The chronic daily intake was calculated using the following equation:

$$CDI\left(\frac{mg}{kg-day}\right) = \frac{EPC\left(\frac{mg}{kg}\right) x\ EF\left(\frac{days}{year}\right) x\ ED\ (years) x\ IR\left(\frac{mg}{day}\right) x\ 0.000001\left(\frac{kg}{mg}\right)}{BW\ (kg) x\ AT\ (years) x\ 365\left(\frac{days}{year}\right)}$$

3. The hazard quotient was calculated using the following equation:

$$HQ\ (unitless) = \frac{CDI\left(\frac{mg}{kg-day}\right)}{RfD\left(\frac{mg}{kg-day}\right)}$$

Prepared by: IMR 08/22/18
Checked by: LMS 08/27/18

Abbreviations:

CAS = Chemical Abstracts Service
CDI - chronic daily intake (mg/kg/day)
HQ = hazard quotient
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day

TABLE 3-4

RISK CHARACTERIZATION - BLACK DUCK, LOCAL CONSUMER
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area	Oral Reference Dose (mg/kg/day)	Food Web Approach			BSAF Approach		
		Exposure Point Concentration - Food Web Approach (mg/kg)	Chronic Daily Intake[2] (mg/kg/day)	HQ[3]	Exposure Point Concentration (mg/kg)	Chronic Daily Intake[2] (mg/kg/day)	HQ[3]
Child Local Consumer							
Pre-Remediation							
Whole River	1.0E-04	0.563	1.3E-04	**1.3**	0.274	6.5E-05	0.65
Mendall Marsh	1.0E-04	0.480	1.1E-04	**1.1**	0.234	5.6E-05	0.56
Verona East	1.0E-04	0.627	1.5E-04	**1.5**	0.305	7.2E-05	0.72
Orland River and East Channel	1.0E-04	0.700	1.7E-04	**1.7**	0.341	8.1E-05	0.81
Southern Cove	1.0E-04	1.23	2.9E-04	**2.9**	0.600	1.4E-04	**1.4**
Current Post-Remediation							
Southern Cove	1.0E-04	1.23	2.9E-04	**2.9**	0.596	1.4E-04	**1.4**
Post-Remediation							
Alternative 1: MNR							
Whole River	1.0E-04	0.563	1.3E-04	**1.3**	0.274	6.5E-05	0.65
Mendall Marsh	1.0E-04	0.480	1.1E-04	**1.1**	0.234	5.6E-05	0.56
Verona East	1.0E-04	0.627	1.5E-04	**1.5**	0.305	7.2E-05	0.72
Orland River and East Channel	1.0E-04	0.700	1.7E-04	**1.7**	0.341	8.1E-05	0.81
Southern Cove	1.0E-04	1.23	2.9E-04	**2.9**	0.596	1.4E-04	**1.4**
Alternative 2: Enhanced MNR, PRG = 500 ng/g							
Whole River	1.0E-04	0.481	1.1E-04	**1.1**	0.234	5.6E-05	0.56
Mendall Marsh	1.0E-04	0.456	1.1E-04	**1.1**	0.222	5.3E-05	0.53
Verona East	1.0E-04	0.520	1.2E-04	**1.2**	0.253	6.0E-05	0.60
Orland River and East Channel	1.0E-04	0.563	1.3E-04	**1.3**	0.274	6.5E-05	0.65
Southern Cove	1.0E-04	0.804	1.9E-04	**1.9**	0.391	9.3E-05	0.93
Alternative 2: Enhanced MNR, PRG = 300 ng/g							
Whole River	1.0E-04	0.439	1.0E-04	**1.0**	0.214	5.1E-05	0.51
Mendall Marsh	1.0E-04	0.456	1.1E-04	**1.1**	0.222	5.3E-05	0.53
Verona East	1.0E-04	0.455	1.1E-04	**1.1**	0.221	5.3E-05	0.53
Orland River and East Channel	1.0E-04	0.497	1.2E-04	**1.2**	0.242	5.7E-05	0.57
Southern Cove	1.0E-04	0.728	1.7E-04	**1.7**	0.354	8.4E-05	0.84
Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal), PRG = 500 ng/g							
Whole River	1.0E-04	0.207	4.9E-05	0.49	0.101	2.4E-05	0.24
Mendall Marsh	1.0E-04	0.480	1.1E-04	**1.1**	0.234	5.6E-05	0.56
Verona East	1.0E-04	0.138	3.3E-05	0.33	0.067	1.6E-05	0.16
Orland River and East Channel	1.0E-04	0.138	3.3E-05	0.33	0.067	1.6E-05	0.16
Southern Cove	1.0E-04	0.672	1.6E-04	**1.6**	0.327	7.8E-05	0.78
Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal), PRG = 300 ng/g							
Whole River	1.0E-04	0.202	4.8E-05	0.48	0.098	2.3E-05	0.23
Mendall Marsh	1.0E-04	0.480	1.1E-04	**1.1**	0.234	5.6E-05	0.56
Verona East	1.0E-04	0.138	3.3E-05	0.33	0.067	1.6E-05	0.16
Orland River and East Channel	1.0E-04	0.138	3.3E-05	0.33	0.067	1.6E-05	0.16
Southern Cove	1.0E-04	0.650	1.5E-04	**1.5**	0.316	7.5E-05	0.75
Alternative 4: Thin Layer Cap							
Whole River	1.0E-04	0.542	1.3E-04	**1.3**	0.264	6.3E-05	0.63
Mendall Marsh	1.0E-04	0.377	9.0E-05	0.90	0.183	4.4E-05	0.44
Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Cap							
Whole River	1.0E-04	0.517	1.2E-04	**1.2**	0.252	6.0E-05	0.60
Mendall Marsh	1.0E-04	0.254	6.0E-05	0.60	0.123	2.9E-05	0.29

Notes:

1. Yellow highlighting and bold text signifies that the reported HQ is above than the target HQ of 1.0
2. The chronic daily intake was calculated using the following equation:

$$CDI\left(\frac{mg}{kg-day}\right) = \frac{EPC\left(\frac{mg}{kg}\right) x\ EF\left(\frac{days}{year}\right) x\ ED\ (years) x\ IR\left(\frac{mg}{day}\right) x\ 0.000001\left(\frac{kg}{mg}\right)}{BW\ (kg) x\ AT\ (years) x\ 365\left(\frac{days}{year}\right)}$$

Prepared by: IMR 08/22/18
Checked by: LMS 08/27/18

3. The hazard quotient was calculated using the following equation:

$$HQ\ (unitless) = \frac{CDI\left(\frac{mg}{kg-day}\right)}{RfD\left(\frac{mg}{kg-day}\right)}$$

Abbreviations:

CAS = Chemical Abstracts Service
CDI - chronic daily intake (mg/kg/day)
HQ = hazard quotient
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day

TABLE 3-5

RISK CHARACTERIZATION - LOBSTER, LOCAL CONSUMER
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area	Oral Reference Dose (mg/kg/day)	Food Web Approach			BSAF Approach		
		Exposure Point Concentration - Food Web Approach (mg/kg)	Chronic Daily Intake[2] (mg/kg/day)	HQ[3]	Exposure Point Concentration (mg/kg)	Chronic Daily Intake[2] (mg/kg/day)	HQ[3]
Child Subsistence Consumer							
Pre-Remediation[4]							
American Lobster							
2014 Lobster Closure Area	1.0E-04	0.182	4.9E-06	0.049	0.211	5.7E-06	0.057
2016 Lobster Closure Area	1.0E-04	0.172	4.7E-06	0.047	0.200	5.4E-06	0.054
2014 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.250	6.8E-06	0.068
2016 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.237	6.4E-06	0.064
Post-Remediation							
Alternative 1: MNR							
2014 Lobster Closure Area	1.0E-04	0.182	4.9E-06	0.049	0.211	5.7E-06	0.057
2016 Lobster Closure Area	1.0E-04	NC	NC	NC	NC	NC	NC
2014 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.250	6.8E-06	0.068
2016 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	NC	NC	NC
Alternative 2: Enhanced MNR, PRG = 500 ng/g							
2014 Lobster Closure Area	1.0E-04	0.171	4.6E-06	0.046	0.199	5.4E-06	0.054
2016 Lobster Closure Area	1.0E-04	NC	NC	NC	NC	NC	NC
2014 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.236	6.4E-06	0.064
2016 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	NC	NC	NC
Alternative 2: Enhanced MNR, PRG = 300 ng/g							
2014 Lobster Closure Area	1.0E-04	0.143	3.9E-06	0.039	0.166	4.5E-06	0.045
2016 Lobster Closure Area	1.0E-04	NC	NC	NC	NC	NC	NC
2014 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.197	5.3E-06	0.053
2016 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	NC	NC	NC
Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal), PRG = 500 ng/g							
2014 Lobster Closure Area	1.0E-04	0.173	4.7E-06	0.047	0.201	5.4E-06	0.054
2016 Lobster Closure Area	1.0E-04	NC	NC	NC	NC	NC	NC
2014 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.238	6.4E-06	0.064
2016 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	NC	NC	NC
Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal), PRG = 300 ng/g							
2014 Lobster Closure Area	1.0E-04	0.121	3.3E-06	0.033	0.140	3.8E-06	0.038
2016 Lobster Closure Area	1.0E-04	NC	NC	NC	NC	NC	NC
2014 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	0.166	4.5E-06	0.045
2016 Lobster Closure Area - Upper Bound BSAF	1.0E-04	--	--	--	NC	NC	NC

Notes:

1. Yellow highlighting and bold text signifies that the reported HQ is above than the target HQ of 1.0
2. The chronic daily intake was calculated using the following equation:

$$CDI\left(\frac{mg}{kg-day}\right) = \frac{EPC\left(\frac{mg}{kg}\right) x\ EF\left(\frac{days}{year}\right) x\ ED\ (years) x\ IR\left(\frac{mg}{day}\right) x\ 0.000001\left(\frac{kg}{mg}\right)}{BW\ (kg) x\ AT\ (years) x\ 365\left(\frac{days}{year}\right)}$$

3. The hazard quotient was calculated using the following equation:

$$HQ\ (unitless) = \frac{CDI\left(\frac{mg}{kg-day}\right)}{RfD\left(\frac{mg}{kg-day}\right)}$$

4. Risk was run for lobster for both the 2014 and 2016 closure areas as it was determined that HQs greater than 1.0 existing for both areas.

Abbreviations:
CAS = Chemical Abstracts Service
CDI - chronic daily intake (mg/kg/day)
HQ = hazard quotient
mg/kg = milligrams per kilogram
mg/kg/day = milligrams per kilogram per day
NC = No change from Pre-Remedial Concentration
-- = Not calculated

Prepared by: IMR 08/22/18
Checked by: LMS 08/27/18

TABLE 3-6

HUMAN HEALTH RISK REDUCTION - SUMMARY OF HAZARD QUOTIENTS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

					Post-Remediation													
	Pre-Remediation		Current Post-Remediation		Alternative 1: MNR		Alternative 2: Enhanced MNR				Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal)				Alternative 4: Thin Layer Cap		Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Cap	
							PRG = 500 ng/g		PRG = 300 ng/g		PRG = 500 ng/g		PRG = 300 ng/g					
Exposure Area	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach	Hazard Quotient (HQ) - Food Web Approach	Hazard Quotient (HQ) - BSAF Approach
Local Consumer - Child																		
Trophic Level 4 Finfish - American Eel																		
Freshwater Area (Bangor to Frankfort Flats)	**1.1**	0.89	--	--	**1.1**	0.89	0.99	0.77	0.85	0.66	0.85	0.66	0.38	0.29	--	--	--	--
Bangor	1.0	0.78	--	--	1.0	0.78	0.95	0.73	0.78	0.60	1.0	0.78	0.35	0.27	--	--	--	--
Orrington	**1.5**	**1.2**	--	--	**1.5**	**1.2**	**1.2**	0.94	1.0	0.80	0.99	0.77	0.34	0.26	--	--	--	--
Frankfort Flats	0.99	0.77	--	--	0.99	0.77	0.88	0.68	0.77	0.60	0.75	0.58	0.43	0.33	--	--	--	--
Orland River and East Channel	**1.4**	**1.1**	--	--	**1.4**	**1.1**	**1.1**	0.89	0.98	0.76	0.62	0.48	0.62	0.48	--	--	--	--
Southern Cove	**1.7**	**1.3**	**1.7**	**1.3**	**1.7**	**1.3**	**1.3**	1.0	**1.1**	0.88	1.0	0.77	0.34	0.26	--	--	--	--
Trophic Level 4 Waterfowl - American Black Duck																		
Whole River	**1.3**	0.65	--	--	**1.3**	0.65	**1.1**	0.56	1.0	0.51	0.49	0.24	0.48	0.23	**1.3**	0.63	**1.2**	0.60
Mendall Marsh	**1.1**	0.56	--	--	**1.1**	0.56	**1.1**	0.53	**1.1**	0.53	**1.1**	0.56	**1.1**	0.23	0.90	0.44	0.60	0.29
Verona East	**1.5**	0.72	--	--	**1.5**	0.72	**1.2**	0.60	**1.1**	0.53	0.33	0.16	0.33	0.16	--	--	--	--
Orland River and East Channel	**1.7**	0.81	--	--	**1.7**	0.81	**1.3**	0.65	**1.2**	0.57	0.33	0.16	0.33	0.16	--	--	--	--
Southern Cove	**2.9**	**1.4**	**2.9**	**1.4**	**2.9**	**1.4**	**1.9**	0.93	**1.7**	0.84	**1.6**	0.78	**1.5**	0.75	--	--	--	--
Trophic Level 3 Shellfish - Lobster																		
2014 Lobster Closure Area	0.049	0.057	--	--	0.049	0.057	0.046	0.054	0.039	0.045	0.047	0.054	0.033	0.038	--	--	--	--
2016 Lobster Closure Area	0.047	0.054	--	--	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	--	--	--	--
2014 Lobster Closure Area - Upper Bound BSAF	--	0.068	--	--	--	0.068	--	0.064	--	0.053	--	0.064	--	0.045	--	--	--	--
2016 Lobster Closure Area - Upper Bound BSAF	--	0.064	--	--	--	NC	--	NC	--	NC	--	NC	--	NC	--	--	--	--

Notes:
1. Bolded cells indicate an HQ>1
2. Teal shaded cells indicate that the Post-Remediation HQ is less than the Pre-Remediation HQ
3. Grey shaded cells indicate that the Post-Remediation HQ is less than the Pre-Remediation HQ but above a value of 1

Prepared by: IMR 08/22/18
Checked by: LMS 08/27/18

Abbreviations:
ng/g = nanograms per gram
NA = not applicable
NC = No change from Pre-Remediation Concentration
-- = Not Calculated

TABLE 3-7

HUMAN HEALTH RISK REDUCTION - SUMMARY OF METHYL MERCURY TISSUE CONCENTRATIONS
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

					Post-Remediation													
							Alternative 2: Enhanced MNR				Alternative 3: Dredging (Surface Deposits, Subtidaland Intertidal)						Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Cap	
	Pre-Remediation		Current Post-Remediation		Alternative 1: MNR		PRG = 500 ng/g		PRG = 300 ng/g		PRG = 500 ng/g		PRG = 300 ng/g		Alternative 4: Thin Layer Cap			
Exposure Area	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach	Tissue Concentration of Methyl Mercury (ng/g) - Food Web Approach	Tissue Concentration of Methyl Mercury (ng/g) - BSAF Approach
Local Consumer - Child																		
Trophic Level 4 Finfish - American Eel																		
Freshwater Area (Bangor to Frankfort Flats)	**340**	**264**	--	--	**340**	**264**	**296**	**230**	**253**	196	**255**	198	113	88	--	--	--	--
Bangor	**300**	**233**	--	--	**300**	**233**	**282**	**219**	**232**	180	**300**	**233**	104	81	--	--	--	--
Orrington	**446**	**346**	--	--	**446**	**346**	**361**	**280**	**306**	**237**	**297**	**230**	102	79	--	--	--	--
Frankfort Flats	**295**	**229**	--	--	**295**	**229**	**262**	**204**	**230**	179	**224**	174	128	100	--	--	--	--
Orland River and East Channel	**422**	**328**	--	--	**422**	**328**	**342**	**266**	**294**	**228**	184	143	184	143	--	--	--	--
Southern Cove	**511**	**397**	**509**	**395**	**509**	**395**	**392**	**304**	**337**	**262**	**298**	**231**	100	78	--	--	--	--
Trophic Level 4 Waterfowl - American Black Duck																		
Whole River	**563**	**274**	--	--	**563**	**274**	**481**	**234**	**439**	**214**	**207**	101	**202**	98	**542**	**264**	**517**	**252**
Mendall Marsh	**480**	**234**	--	--	**480**	**234**	**456**	**222**	**456**	**222**	**480**	**234**	**480**	**234**	**377**	183	**254**	123
Verona East	**627**	**305**	--	--	**627**	**305**	**520**	**253**	**455**	**221**	138	67	138	67	--	--	--	--
Orland River and East Channel	**700**	**341**	--	--	**700**	**341**	**563**	**274**	**497**	**242**	138	67	138	67	--	--	--	--
Southern Cove	**1234**	**600**	**1226**	**596**	**1226**	**596**	**804**	**391**	**728**	**354**	**672**	**327**	**650**	**316**	--	--	--	--
Trophic Level 3 Shellfish - Lobster																		
2014 Lobster Closure Area	182	**211**	--	--	182	**211**	171	199	143	166	173	**201**	121	140	--	--	--	--
2016 Lobster Closure Area	172	200	--	--	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	--	--	--	--
2014 Lobster Closure Area - Upper Bound BSAF	--	**250**	--	--	--	**250**	--	**236**	--	197	--	**238**	--	166	--	--	--	--
2016 Lobster Closure Area - Upper Bound BSAF	--	**237**	--	--	--	NC	--	NC	--	NC	--	NC	--	NC	--	--	--	--

Notes:
1. Bolded cells indicate an methyl mercury tissue concentration greater than the MeCDC fish tissue action level of 200 ng/g
2. Teal shaded cells indicate that the Post-Remediation methyl mercury tissue concentration is less than the Pre-Remediation methyl mercury tissue concentration
3. Grey shaded cells indicate that the Post-Remediation methyl mercury tissue concentration is less than the Pre-Remediation methyl mercury tissue concentration but above a concentration of 200 ng/g

Prepared by: IMR 08/22/18
Checked by: NSR 08/29/18

Abbreviations:
ng/g = nanograms per gram
NA = not applicable
NC = No change from Pre-Remediation Concentration
-- = Not Calculated

TABLE 4-1

RESULTS OF THE BASELINE ECOLOGICAL RISK ASSESSMENT - TISSUE HQs
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Receptor	Media (Date Range)	Exposure Area	Tissue Hazard Quotients[1]			
			Mercury		Methyl Mercury	
			NOAEL	LOAEL	NOAEL	LOAEL
American lobster	Tail tissue (2016 - 2017)	Odom Ledge	0.29	--	0.26	--
		South Verona	0.24	--	0.22	--
		Cape Jellison	0.16	--	0.14	--
		Turner Point	0.13	--	0.12	--
		Harborside	0.062	--	0.057	--
		2014 Closure	0.26	--	0.24	--
		2016 Closure	0.14	--	0.13	--
		Frenchman Bay$_{REF}$	0.024	--	0.022	--
Blue mussel	Whole body tissue (2016 - 2017)	ES-15	**1.4**	0.73	0.61	0.31
		ES-13	**1.7**	0.88	0.74	0.38
		ES03	**2.1**	**1.0**	0.88	0.45
		Fort Point	**1.8**	0.92	0.78	0.39
		Frenchman Bay$_{REF}$	0.19	0.096	0.081	0.041
Mummichog	Whole body tissue (2016 - 2017)	BO4	0.26	0.26	0.23	0.23
		OB5	0.21	0.21	0.18	0.18
		OB1	0.33	0.33	0.28	0.28
		Mendall Marsh	0.34	0.34	0.30	0.30
		Frenchman Bay$_{REF}$	0.017	0.017	0.015	0.015
Rainbow smelt	Whole body tissue (2016 - 2017)	OB-01	0.17	0.17	0.13	0.13
		OB-04	0.16	0.16	0.13	0.13
		OB-05	0.40	0.40	0.32	0.32
		ES-13	0.12	0.12	0.091	0.091
		Fort Point	0.19	0.19	0.15	0.15
		Frenchman Bay$_{REF}$	0.026	0.026	0.021	0.021
Atlantic tomcod	Fillet tissue (2016 - 2017)	BO4	**3.1**	0.31	**2.5**	0.25
		OB5	**2.4**	0.24	**1.9**	0.19
		OB1	**2.7**	0.27	**2.1**	0.21
		ES13	**1.8**	0.18	**1.4**	0.14
		Fort Point	0.96	0.096	0.77	0.077
		Frenchman Bay$_{REF}$	0.47	0.047	0.38	0.038
American eel	Fillet tissue (2016 - 2017)	BO-04	**9.1**	0.91	**7.9**	0.79
		OB-05	**4.9**	0.49	**4.3**	0.43
		OB-01	**5.1**	0.51	**4.5**	0.45
		OV-04$_{REF}$	**4.2**	0.42	**3.6**	0.36
American black duck	Blood (2014, 2017, 2018)	Mendall Marsh	**2.2**	0.22	**1.7**	0.17
		ES-13	**1.4**	0.14	**1.1**	0.11
		Frenchman Bay$_{REF}$	0.37	0.037	0.29	0.029
Nelson's sparrow	Blood (2016 - 2017)	W-17-N	**23**	**2.3**	**22**	**2.2**
		MMSE	**24**	**2.4**	**23**	**2.3**
		MMSW	**23**	**2.3**	**22**	**2.2**
		Pleasant River$_{REF}$	**2.2**	0.22	**2.1**	0.21
Red-winged blackbird	Blood (2016 - 2017)	W-17-N	**20**	**2.0**	**19**	**1.9**
		MMSE	**30**	**3.0**	**29**	**2.9**
		MMSW	**36**	**3.6**	**34**	**3.4**

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Prepared by: IMR 08/13/18
Checked by: LO 08/14/18

Abbreviations:
HQ = hazard quotient
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

TABLE 4-2

RESULTS OF THE BASELINE ECOLOGICAL RISK ASSESSMENT - DIETARY HQs
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

		Dietary Hazard Quotients[1]			
		Mercury		Methyl Mercury	
Endpoint Receptor	Exposure Area	NOAEL	LOAEL	NOAEL	LOAEL
Mummichog	Mendall Marsh	0.17	0.17	0.095	0.095
	Estuary	0.16	0.16	0.081	0.081
	Reference	0.055	0.055	0.036	0.036
Rainbow smelt	Estuary	0.19	0.19	0.15	0.15
	Reference	0.02	0.02	0.007	0.007
Atlantic tomcod	Estuary	0.163	0.016	0.116	0.011
	Reference	0.015	0.001	0.0035	0.0003
American eel	Estuary	0.70	0.068	0.29	0.028
	$OV\text{-}04_{REF}$	0.08	0.008	0.03	0.003
Nelson's sparrow	W-17-N	**3.4**	0.34	**1.8**	0.18
	MMSE	**6.3**	0.63	**2.6**	0.26
	MMSW	**2.2**	0.22	**1.3**	0.13
	$Pleasant\ River_{REF}$	0.63	0.063	0.44	0.044
Red-winged blackbird	W-17-N	**1.8**	0.18	**1.1**	0.11
	MMSE	**4.2**	0.42	**1.7**	0.17
	MMSW	**1.0**	0.10	0.76	0.076
	$Pleasant\ River_{REF}$	0.44	0.044	0.31	0.031
American black duck	Mendall Marsh	**1.5**	0.15	0.11	0.011
	Estuary	0.69	0.069	0.11	0.011
	$Frenchman\ Bay_{REF}$	0.055	0.0055	0.012	0.0012
Belted Kingfisher	BO-04	0.77	0.52	0.61	0.41
	OB-05	0.59	0.40	0.47	0.32
	OB-04	0.35	0.24	0.28	0.19
	OB-01	0.73	0.49	0.59	0.40
	MM	0.95	0.65	0.78	0.53
	ES-13	0.34	0.23	0.27	0.18
	ES-FP	0.53	0.36	0.44	0.30
	$Frenchman\ Bay_{REF}$	0.059	0.040	0.049	0.033
Bald Eagle	BO-04	0.69	0.47	0.56	0.38
	OB-05	0.69	0.47	0.56	0.38
	OB-04	0.40	0.27	0.32	0.22
	OB-01	0.40	0.27	0.33	0.22
	MM	0.51	0.35	0.42	0.28
	ES-13	0.22	0.15	0.17	0.12
	ES-FP	0.18	0.12	0.15	0.10
	$Frenchman\ Bay_{REF}$	0.18	0.12	0.15	0.10
Mink	BO-04	0.23	0.14	0.17	0.11
	OB-05	0.18	0.11	0.14	0.088
	OB-04	0.13	0.083	0.10	0.065
	OB-01	0.21	0.13	0.16	0.10
	MM	0.28	0.17	0.22	0.14
	ES-13	0.10	0.062	0.075	0.047
	ES-FP	0.15	0.094	0.12	0.078
	$Frenchman\ Bay_{REF}$	0.017	0.011	0.014	0.0087

Notes:
1. **Bolded** HQ indicates a HQ ≥ 1.0

Prepared by: LO 08/08/18
Checked by: IMR 08/08/18

Abbreviations:
LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

TABLE 4-3

CONCENTRATIONS OF TOTAL MERCURY IN MARSH SONGBIRD BLOOD FOR ECOLOGICAL RISK REDUCTION
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Pre-Remediation (ng/g)		Current Post-Remediation (ng/g)		Post Remediation (ng/g)					
					Alternative 1: MNR		Alternative 2: Enhanced MNR			
							PRG = 500 ng/g		PRG = 300 ng/g	
	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach
Nelson's Sparrow										
Mendall Marsh - West	2,464	3,949	--	--	NC	NC	2,338	3,747	2,208	3,539
Mendall Marsh - East	2,339	3,749	--	--	NC	NC	2,243	3,594	2,136	3,424
Southern Cove	6,059	9,712	6,021	9,650	6,021	9,650	3,950	6,331	3,574	5,729
Red-Winged Blackbird										
Mendall Marsh - West	3,936	2,857	--	--	NC	NC	3,734	2,710	3,527	2,560
Mendall Marsh - East	3,736	2,712	--	--	NC	NC	3,582	2,600	3,413	2,477
Southern Cove	9,679	7,025	9,618	6,980	9,618	6,980	6,310	4,580	5,709	4,144

Abbreviations:
ng/g = nanograms per gram
MNR = Monitored Natural Recovery
PRG = Preliminary Remedial Goal
BSAF = Biota-Sediment Accumulation Factor
NC = No change from Pre-Remediation Concentration
-- = Not Calculated

TABLE 4-3

CONCENTRATIONS OF TOTAL MERCURY IN MARSH SONGBIRD BLOOD FOR ECOLOGICAL RISK REDUCTION
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Post Remedation (ng/g)							
	Alternative 3: Dredging (Surface Deposits, Subtidal, Intertidal)				Alternative 4: Thin-Layer Capping		Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Capping	
	PRG = 500 ng/g		PRG = 300 ng/g					
	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach	Concentration in Tissue - Food Web Approach	Concentration in Tissue - BSAF Approach
Nelson's Sparrow								
Mendall Marsh - West	1,951	3,127	1,951	3,127	2,030	3,253	1,646	2,638
Mendall Marsh - East	2,339	3,749	2,339	3,749	1,888	3,026	1,355	2,173
Southern Cove	3,299	5,288	3,193	5,117	--	--	--	--
Red-Winged Blackbird								
Mendall Marsh - West	3,116	2,262	3,116	2,262	3,242	2,353	2,629	1,908
Mendall Marsh - East	3,736	2,712	3,736	2,712	3,015	2,189	2,165	1,571
Southern Cove	5,270	3,825	5,100	3,702	--	--	--	--

Prepared by: IMR 08/22/18
Checked by: NSR 08/27/18

Abbreviations:
ng/g = nanograms per gram
MNR = Monitored Natural Recovery
PRG = Preliminary Remedial Goal
BSAF = Biota-Sediment Accumulation Factor
NC = No change from Pre-Remediation Concentration
-- = Not Calculated

TABLE 4-4

MARSH SONGBIRD BLOOD HAZARD QUOTIENTS FOR ECOLOGICAL RISK REDUCTION
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Pre-Remediation		Current Post-Remediation		Post-Remediation					
					Alternative 1: MNR		Alternative 2: Enhanced MNR			
							PRG = 500 ng/g		PRG = 300 ng/g	
	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach
Nelson's Sparrow										
NOAEL HQs - Blood NOAEL TRV of 210 ng/g										
Mendall Marsh - West	**12**	**19**	--	--	NC	NC	**11**	**18**	**11**	**17**
Mendall Marsh - East	**11**	**18**	--	--	NC	NC	**11**	**17**	**10**	**16**
Southern Cove	**29**	**46**	**29**	**46**	**29**	**46**	**19**	**30**	**17**	**27**
LOAEL HQs - Blood LOAEL TRV of 2,100 ng/g										
Mendall Marsh - West	**1.2**	**1.9**	--	--	NC	NC	**1.1**	**1.8**	**1.1**	**1.7**
Mendall Marsh - East	**1.1**	**1.8**	--	--	NC	NC	**1.1**	**1.7**	1.0	**1.6**
Southern Cove	**2.9**	**4.6**	**2.9**	**4.6**	**2.9**	**4.6**	**1.9**	**3.0**	**1.7**	**2.7**
Red-winged Blackbird										
NOAEL HQs - Blood NOAEL TRV of 210 ng/g										
Mendall Marsh - West	**19**	**14**	--	--	NC	NC	**18**	**13**	**17**	**12**
Mendall Marsh - East	**18**	**13**	--	--	NC	NC	**17**	**12**	**16**	**12**
Southern Cove	**46**	**33**	**46**	**33**	**46**	**33**	**30**	**22**	**27**	**20**
LOAEL HQs - Blood LOAEL TRV of 2,100 ng/g										
Mendall Marsh - West	**1.9**	**1.4**	--	--	NC	NC	**1.8**	**1.3**	**1.7**	**1**
Mendall Marsh - East	**1.8**	**1.3**	--	--	NC	NC	**1.7**	**1.2**	**1.6**	**1**
Southern Cove	**4.6**	**3.3**	**4.6**	**3.3**	**4.6**	**3.3**	**3.0**	**2.2**	**2.7**	**2.0**

Abbreviations:
HQ = Hazard Quotient
MNR = Monitored Natural Recovery
PRG = Preliminary Remedial Goal
BSAF = Biota-Sediment Accumulation Factor
NC = No change from Pre-Remediation Concentration
-- = Not Calculated

Notes:
1. Bolded cells indicate an HQ>1.
2. Teal shaded cells indicate that the Post-Remediation HQ is less than the Pre-Remediation HQ and at or below a value of 1.0.
3. Gray shaded cells indicate that the Post-Remediation HQ is less than the Pre-Remediation HQ, but above a value of 1.0. Note that HQs are rounded to 2 significant figures so a slight decrease in a HQ may not be shown in the presented values.

TABLE 4-4

MARSH SONGBIRD BLOOD HAZARD QUOTIENTS FOR ECOLOGICAL RISK REDUCTION
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

	Post-Remediation							
	Alternative 3: Dredging (Surface Deposits, Subtidal, Intertidal)				Alternative 4: Thin-Layer Capping		Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Capping	
	PRG = 500 ng/g		PRG = 300 ng/g					
	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach	HQ - Food Web Approach	HQ - BSAF Approach
Nelson's Sparrow								
NOAEL HQs - Blood NOAEL TRV								
Mendall Marsh - West	**9.3**	**15**	**9.3**	**15**	**9.7**	**15**	**7.8**	**13**
Mendall Marsh - East	**11**	**18**	**11**	**18**	**9.0**	**14**	**6.5**	**10**
Southern Cove	**16**	**25**	**15**	**24**	--	--	--	--
LOAEL HQs - Blood LOAEL TRV								
Mendall Marsh - West	0.93	**1.5**	0.93	**1.5**	0.97	**1.5**	0.78	**1.3**
Mendall Marsh - East	**1.1**	**1.8**	**1.1**	**1.8**	0.90	**1.4**	0.65	1.0
Southern Cove	**1.6**	**2.5**	**1.5**	**2.4**	--	--	--	--
Red-winged Blackbird								
NOAEL HQs - Blood NOAEL TRV of 300 ng/g								
Mendall Marsh - West	**15**	**11**	**15**	**11**	**15**	**11**	**13**	**9.1**
Mendall Marsh - East	**18**	**13**	**18**	**13**	**14**	**10**	**10**	**7.5**
Southern Cove	**25**	**18**	**24**	**18**	--	--	--	--
LOAEL HQs - Blood LOAEL TRV of 3,000 ng/g								
Mendall Marsh - West	**1.5**	**1.1**	**1.5**	**1.1**	**1.5**	**1.1**	**1.3**	0.91
Mendall Marsh - East	**1.8**	**1.3**	**1.8**	**1.3**	**1.4**	1.0	1.0	0.75
Southern Cove	**2.5**	**1.8**	**2.4**	**1.8**	--	--	--	--

Abbreviations:
HQ = Hazard Quotient
MNR = Monitored Natural Recovery
PRG = Preliminary Remedial Goal
BSAF = Biota-Sediment Accumulation Factor
NC = No change from Pre-Remediation Concentration
-- = Not Calculated

Prepared by: IMR 08/22/18
Checked by: NSR 08/27/18

Notes:
1. Bolded cells indicate an HQ>1.
2. Teal shaded cells indicate that the Post-Remediation HQ is less than the Pre-Remediation HQ and at or below a value of 1.0.
3. Gray shaded cells indicate that the Post-Remediation HQ is less than the Pre-Remediation HQ, but above a value of 1.0. Note that HQs are rounded to 2 significant figures so a slight decrease in a HQ may not be shown in the presented values.

TABLE 6-1

SUMMARY OF HUMAN HEALTH AND ECOLOGICAL RISK REDUCTION EVALUATION
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area[1,2]	Alternative 1: MNR		Alternative 2: Enhanced MNR				Alternative 3: Dredging (Surface Deposits, Subtidal, Intertidal, Thalweg)				Alternative 4: Thin-Layer Capping		Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Capping	
			PRG = 500 ng/g		PRG = 300 ng/g		PRG = 500 ng/g		PRG = 300 ng/g					
	Food Web Approach	BSAF Approach	Food Web Approach	BSAF Approach	Food Web Approach	BSAF Approach	Food Web Approach	BSAF Approach	Food Web Approach	BSAF Approach	Food Web Approach	BSAF Approach	Food Web Approach	BSAF Approach
Main Channel of the Penobscot River and the Orland River														
Local Consumer - Child														
American Eel	--	--	--	X	X	X	X	X	**X**	**X**				
American Black Duck	--	X	--	X	--	X	X	**X**	X	**X**				
American Lobster	**X**	X	**X**	**X**	**X**	**X**	**X**	X	**X**	**X**				
American Lobster - Upper End BSAF		X		X		**X**		X		X				
Mendall Marsh														
Local Consumer - Child														
American Black Duck	--	X	--	X	--	X	--	X	--	X	X	**X**	X	**X**
Nelson's Sparrow														
NOAEL TRV	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LOAEL TRV	--	--	--	--	--	--	--	--	--	--	X	--	X	--
Red-winged Blackbird														
NOAEL TRV	--	--	--	--	--	--	--	--	--	--	--	--	--	--
LOAEL TRV	--	--	--	--	--	--	--	--	--	--	--	--	--	X
Southern Cove														
Local Consumer - Child														
American Eel	--	--	--	X	--	X	X	X	**X**	**X**				
American Black Duck	--	--	--	X	--	X	--	X	--	X				
Nelson's Sparrow														
NOAEL TRV	--	--	--	--	--	--	--	--	--	--				
LOAEL TRV	--	--	--	--	--	--	--	--	--	--				
Red-winged Blackbird														
NOAEL TRV	--	--	--	--	--	--	--	--	--	--				
LOAEL TRV	--	--	--	--	--	--	--	--	--	--				

Abbreviations:
X - indicates that the remedial alternative would result in a HQ at or below 1.0
Bolded values indicate that the remedial alternative would result in a tissue concentration less than 200 ng/g
-- = Remedial alternative does not result in an HQ below 1 or a decrease in tissue concentration to less than 200 ng/g where applicable
HQ = Hazard Quotient
MNR = Monitored Natural Recovery
ng/g = nanograms per gram
not applicable as remedial alternative

Prepared by: IMR 08/28/18
Checked by: NSR 08/29/18

Notes:
1. Table includes only those biota with a Pre-remediation HQ above 1.0.
2. Values are marked as having a decrease of an HQ to below 1.0 or a tissue concentration less than 200 ng/g if that is true for all portions of the exposure area.

TABLE 6-2

PERCENT DECREASE OF HUMAN HEALTH AND ECOLOGICAL RISK
RISK REDUCTION REPORT
Penobscot River Phase III Engineering Study
Penobscot River Estuary, Maine

Exposure Area [1,2,3,5]	Alternative 1: MNR	Alternative 2: Enhanced MNR		Alternative 3: Dredging (Surface Deposits, Subtidal, Intertidal)		Alternative 4: Thin-Layer Capping	Alternative 6: Dredging (Intertidal, Subtidal) & Thin-Layer Capping
		PRG = 500 ng/g	PRG = 300 ng/g	PRG = 500 ng/g	PRG = 300 ng/g		
Main Channel of the Penobscot River and the Orland River							
Local Consumer - Child							
American Eel	0%	5.8% - 19%	22% - 31%	0% - 56%	**56% - 77%**		
American Black Duck	0%	14%-20%	22%-29%	63%-80%	64%-80%		
American Lobster	**0%**	5.8%	**21%**	**4.9%**	**34%**		
American Lobster - Upper End BSAF	0%	5.8%	21%	4.9%	34%		
Mendall Marsh							
Local Consumer - Child							
American Black Duck	0%	5.1%	5.1%	0%	0%-58%	22%	47%
Nelson's Sparrow							
NOAEL TRV	0%	4.1%-5.1%	8.7%-10%	0%-21%	0%-21%	18%-19%	33%-42%
LOAEL TRV	0%	4.1%-5.1%	8.7%-10%	0%-21%	0%-21%	18%-19%	33%-42%
Red-winged Blackbird							
NOAEL TRV	0%	4.1%-5.1%	8.7%-10%	0%-21%	0%-21%	18%-19%	33%-42%
LOAEL TRV	0%	4.1%-5.1%	8.7%-10%	0%-21%	0%-21%	18%-19%	33%-42%
Southern Cove [4]							
Local Consumer - Child							
American Eel	0%	23%	34%	42%	**80%**		
American Black Duck	1%	35%	41%	46%	47%		
Nelson's Sparrow							
NOAEL TRV	0.6%	35%	41%	46%	47%		
LOAEL TRV	0.6%	35%	41%	46%	47%		
Red-winged Blackbird							
NOAEL TRV	0.6%	35%	41%	46%	47%		
LOAEL TRV	0.6%	35%	41%	46%	47%		

Abbreviations:
MNR = Monitored Natural Recovery
ng/g = nanograms per gram
not applicable as remedial alternative

Prepared by: IMR 08/28/18
Checked by: NSR 08/29/18

Notes:
1. Table includes only those biota with a Pre-remediation HQ above 1.0.
2. Percent decreases that correspond with an HQ to at or below 1.0 for all portions of the exposure areas are labeled in green.
3. Percent decreases that correspond with an HQ above 1.0 for all portions of the exposure areas are labeled in yellow.
4. Southern Cove percent differences are the percent difference between the current post-remediation concentration and each post-remediation alternative concentration.
5. Bolded values indicate a percent decrease would result in a methyl mercury tissue concentration less than 200 ng/g for American Lobster, American black duck, and American eel.

FIGURES

N

Former Veazie Dam
Eddington
City of Bangor
Bangor
Former HoltraChem Facility
Orrington
Southern Cove
Bald Hill Cove
Orrington
Winterport
Winterport Boat Yard
Frankfort Flats
Bucksport Harbor
Mendall Marsh
Bucksport
Bucksport
Verona Northeast
Prospect
Orland River
Bucksport Thalweg
Verona Island
Verona East
Verona West
South Orland
Fort Point Cove
Upper Penobscot Bay
Fort Point
Cape Jellison
Sears Island
Cape Jellison
Wilson Point
Belfast
Squaw Point
Turner Point
Belfast Bay
Turtle Head
Perkins Point
Castine
Islesboro

Maine
Penobscot River

0 3 6 Miles

Legend

Official Study Reach Boundary

Winterport Official Study Reach Name

Figure 1-1
Site Location and Reaches

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Penobscot River Risk Reduction Report
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 9/6/2018	Checked/Date: NSR 9/6/2018

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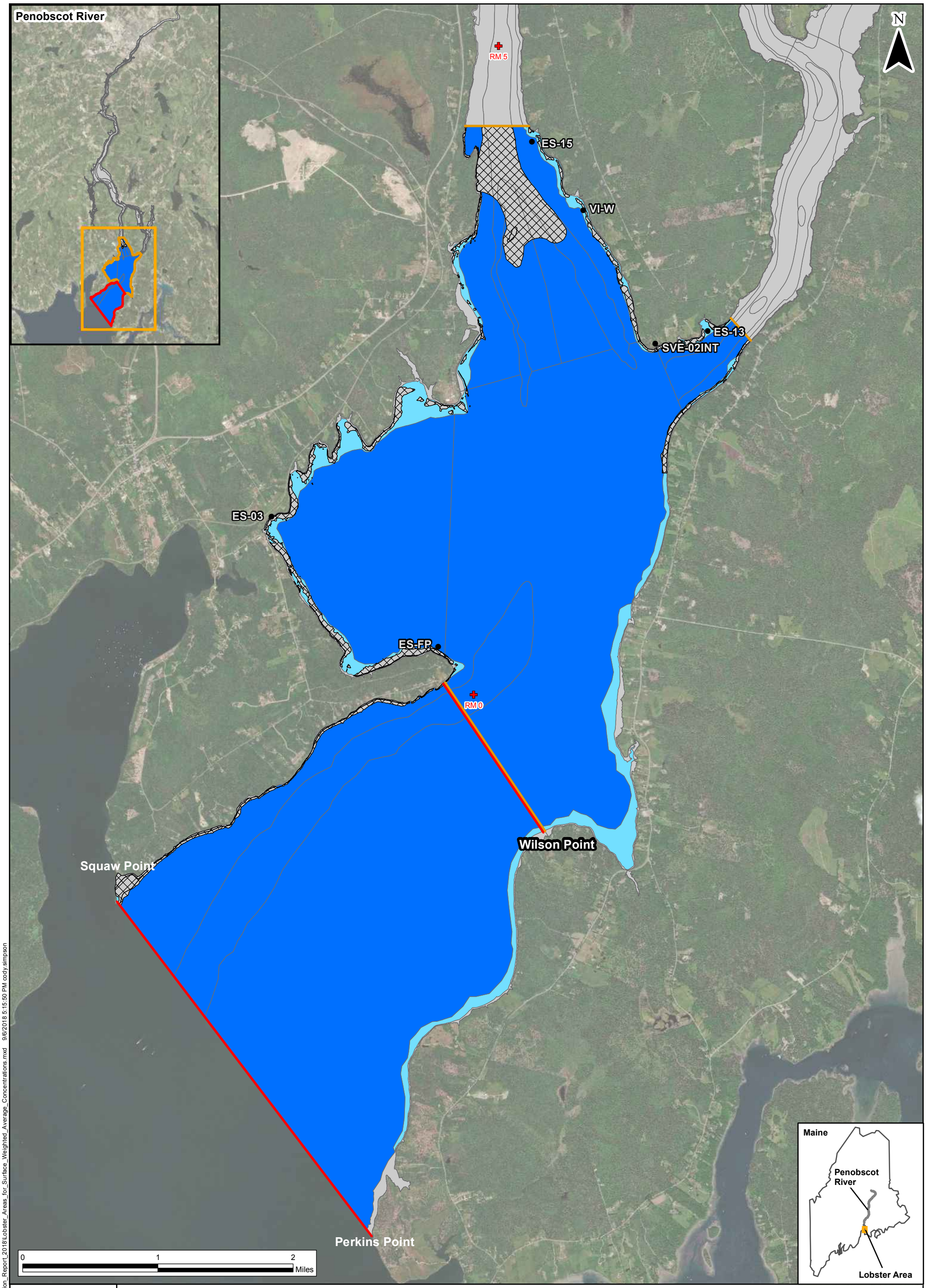

Legend

- River Mile Marker
- Biota Sampling Location
- 2014 Closure Line
- 2016 Closure Line
- Subtidal Area
- Intertidal Area
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-1
Areas Used for the Development of
Surface Area Weighted Average Concentrations - Lobster

Penobscot River Risk Reduction Report
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 9/6/2018	Checked/Date: NSR 9/6/2018

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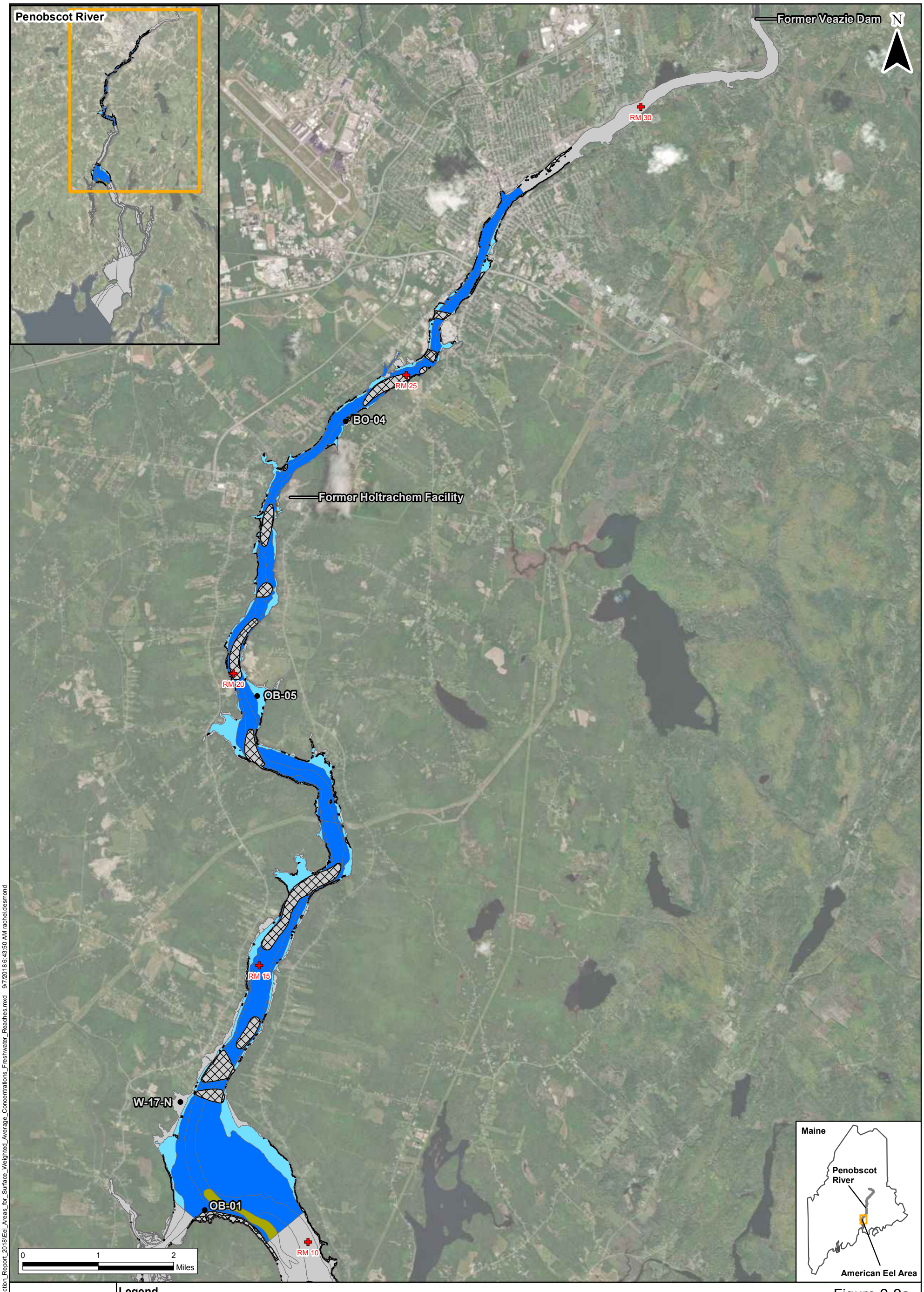

Legend

- River Mile Marker
- Biota Sampling Location
- Subtidal Area
- Intertidal Area
- Southern Cove Excavation Footprint
- Surface Deposit Ribbons
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-2a
Areas Used for the Development of
Surface Area Weighted Average Concentrations -
American Eel - Freshwater Reach

Penobscot River Risk Reduction Report
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 9/7/2018	Checked/Date: NSR 9/7/2018

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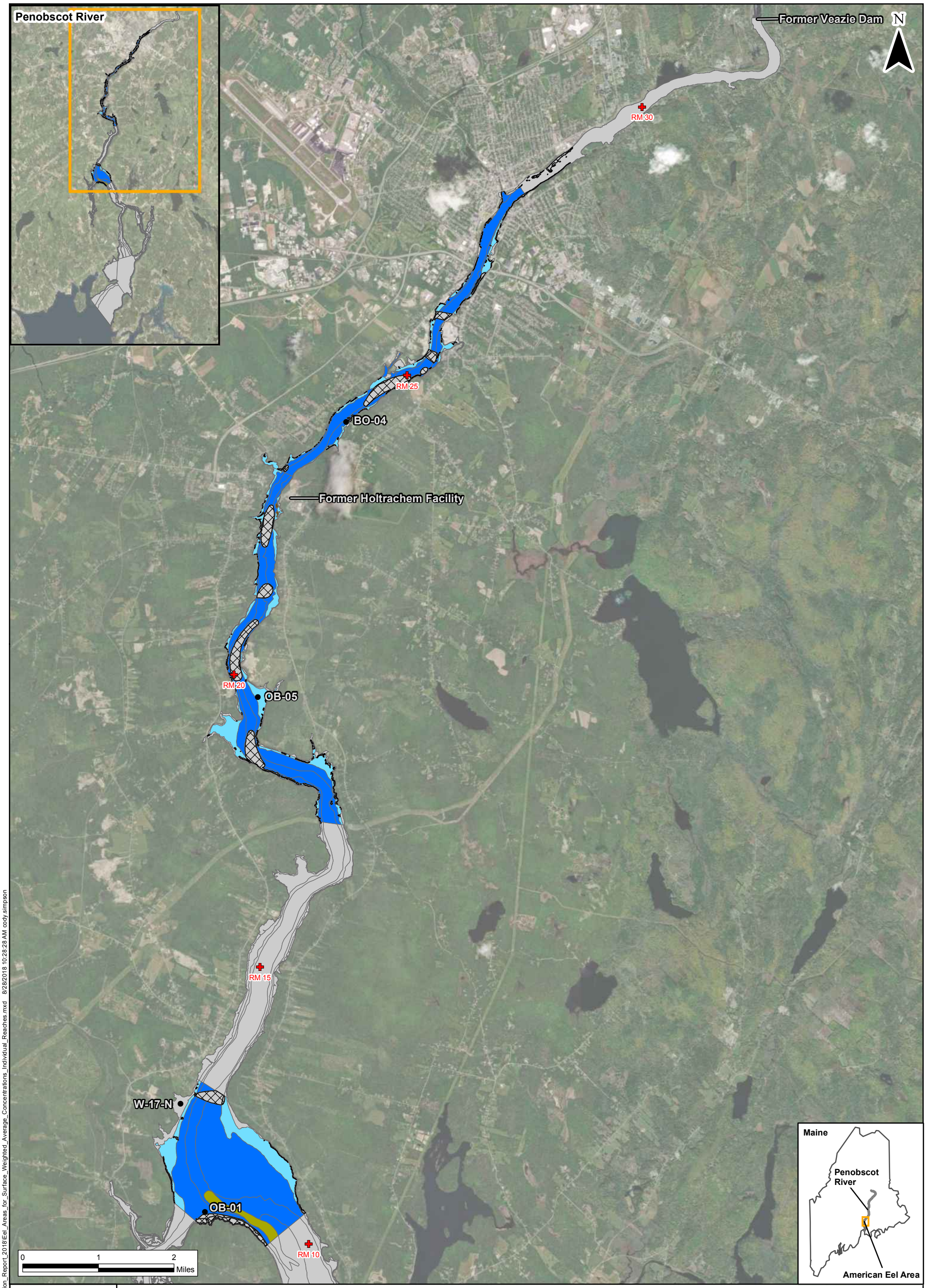

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Legend

- River Mile Marker
- Biota Sampling Location
- Subtidal Area
- Intertidal Area
- Southern Cove Excavation Footprint
- Surface Deposit Ribbons
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

Figure 2-2b
Areas Used for the Development of
Surface Area Weighted Average Concentrations -
American Eel - Individual Reaches

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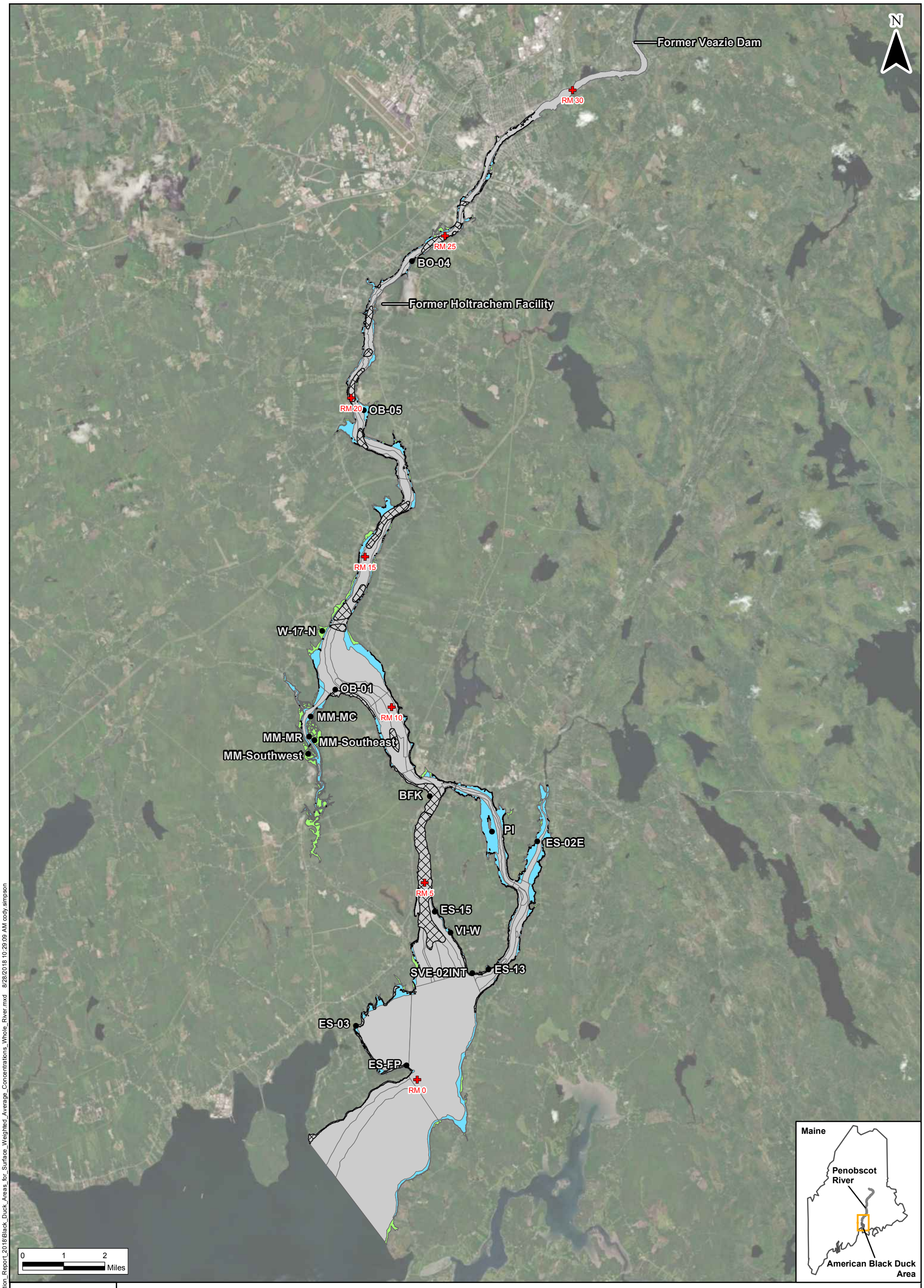
Penobscot River Phase III Engineering Study

Project: 3616166052	Prepared/Date: RD 9/6/2018	Checked/Date: NSR 9/6/2018



Legend

- River Mile Marker
- Biota Sampling Location
- Intertidal Area
- Wetland Area
- Southern Cove Excavation Footprint
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-3a
Areas Used for the Development of Surface Area Weighted Average Concentrations - American Black Duck - Whole River

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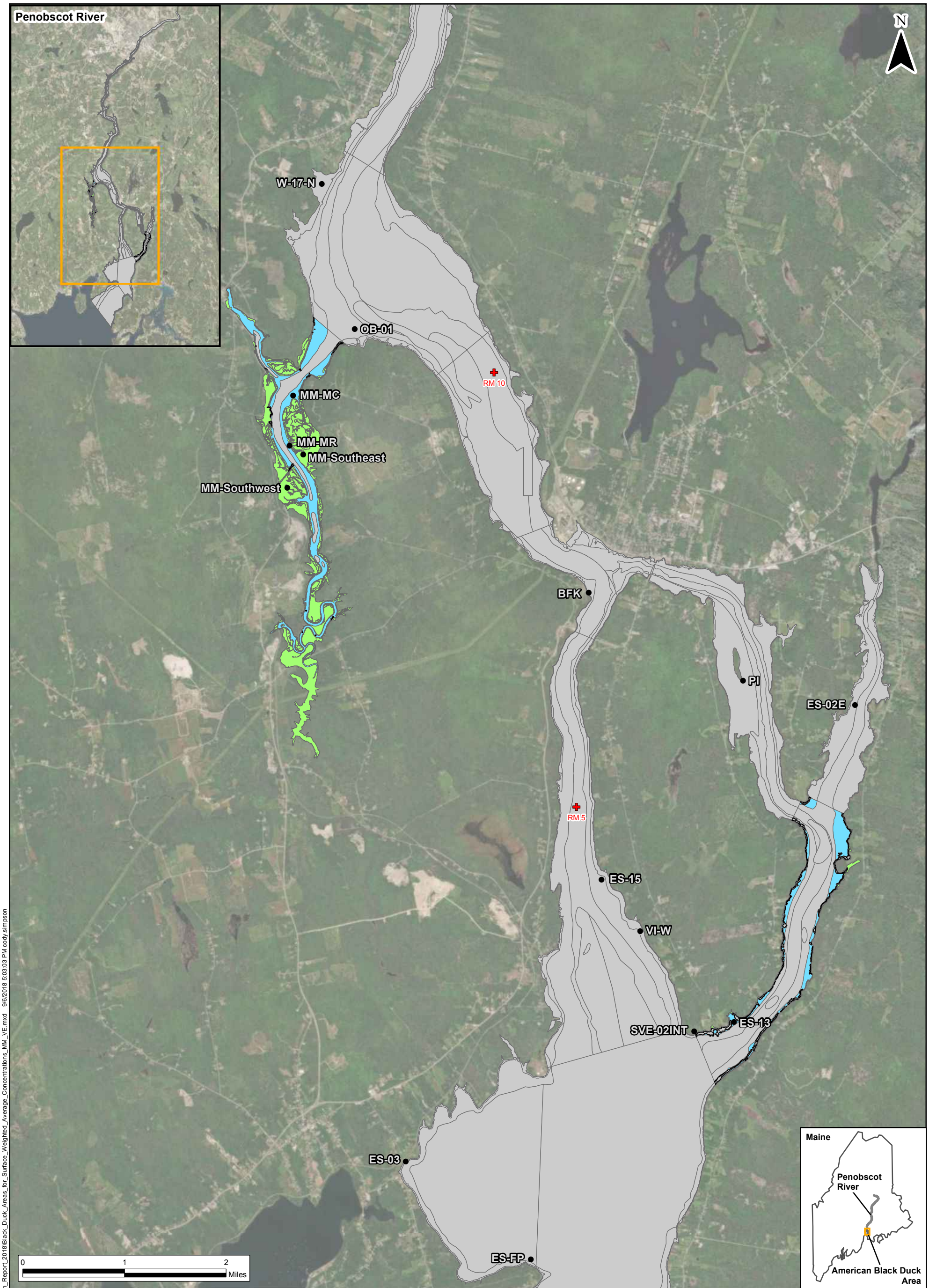

Legend

- River Mile Marker
- Biota Sampling Location
- Intertidal
- Wetland Area
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-3b
Areas Used for the Development of Surface Area Weighted Average Concentrations - American Black Duck - Individual Reaches

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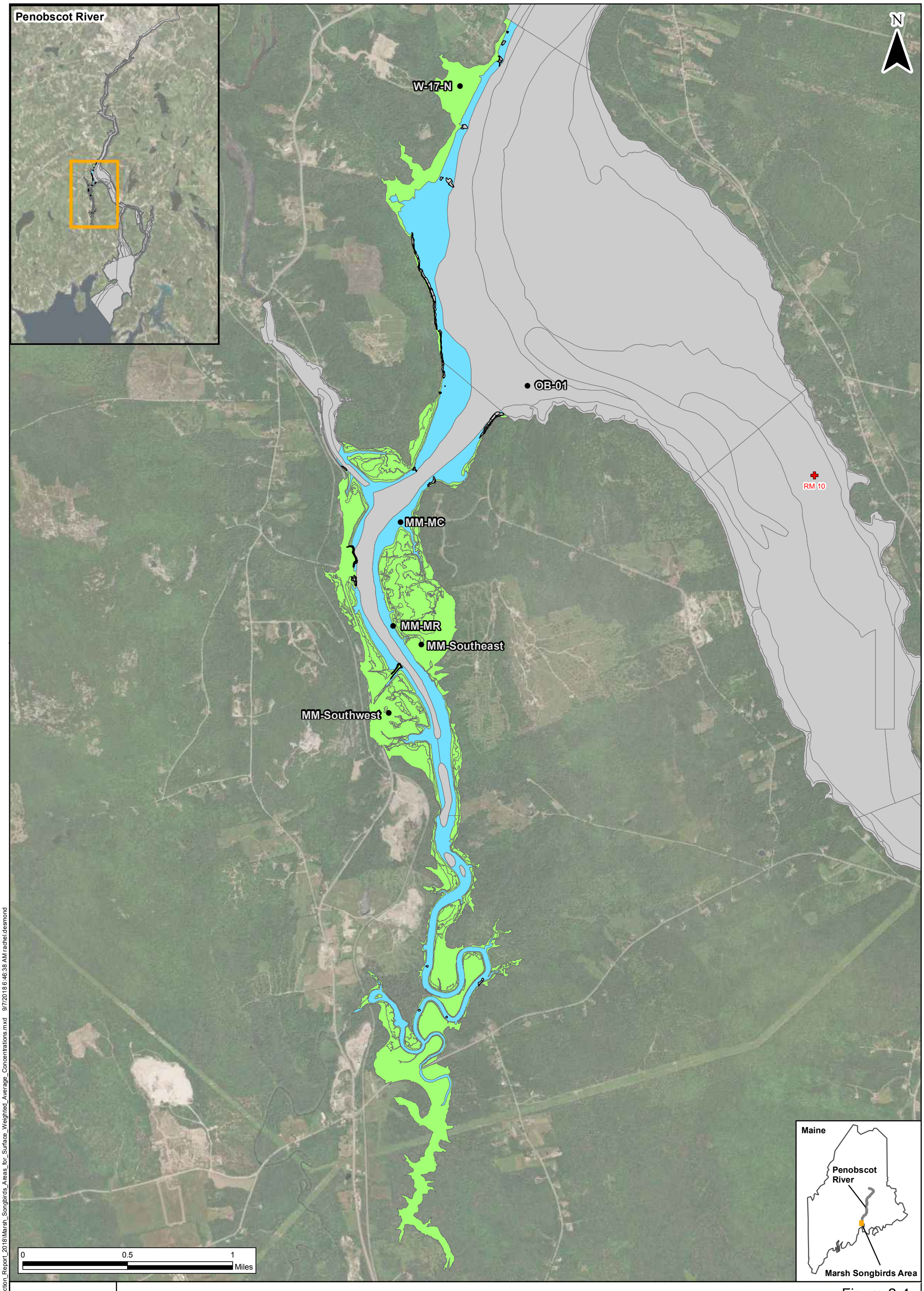

Legend

- River Mile Marker
- Biota Sampling Location
- Intertidal
- Wetland
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-4
Areas Used for the Development of Surface Area Weighted Average Concentrations - Marsh Songbirds

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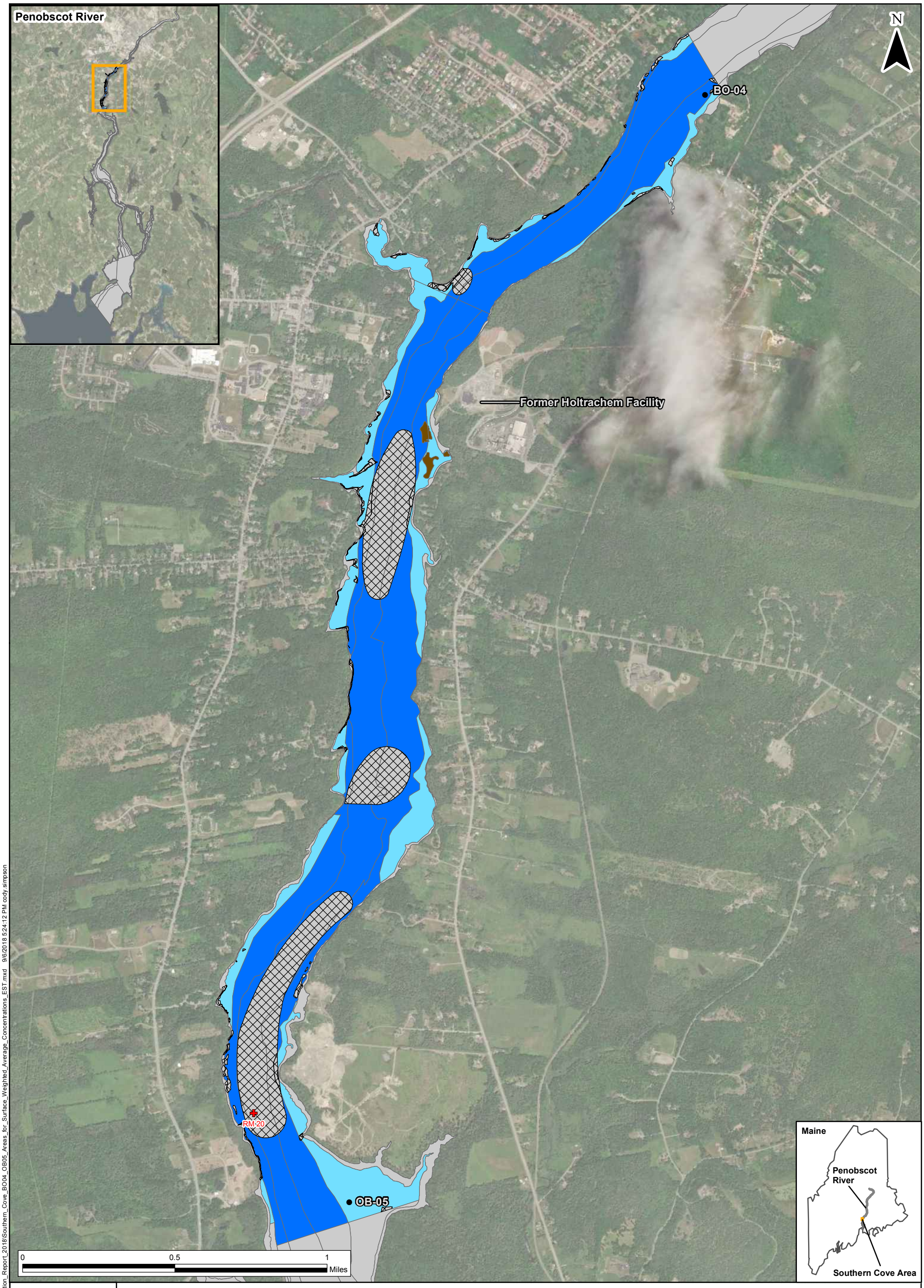
Document: G:\Penobscot River\mxds\Risk_Reduction_Report_2018\Marsh_Songbirds_Areas_for_Surface_Weighted_Average_Concentrations.mxd 9/7/2018 6:46:38 AM rachel.desmond



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Legend

- River Mile Marker
- Biota Sampling Location
- Subtidal Area
- Intertidal Area
- Southern Cove Excavation Footprint
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

Figure 2-5
Areas Used for the Development of Surface Area Weighted Average Concentrations - Southern Cove (Fish)

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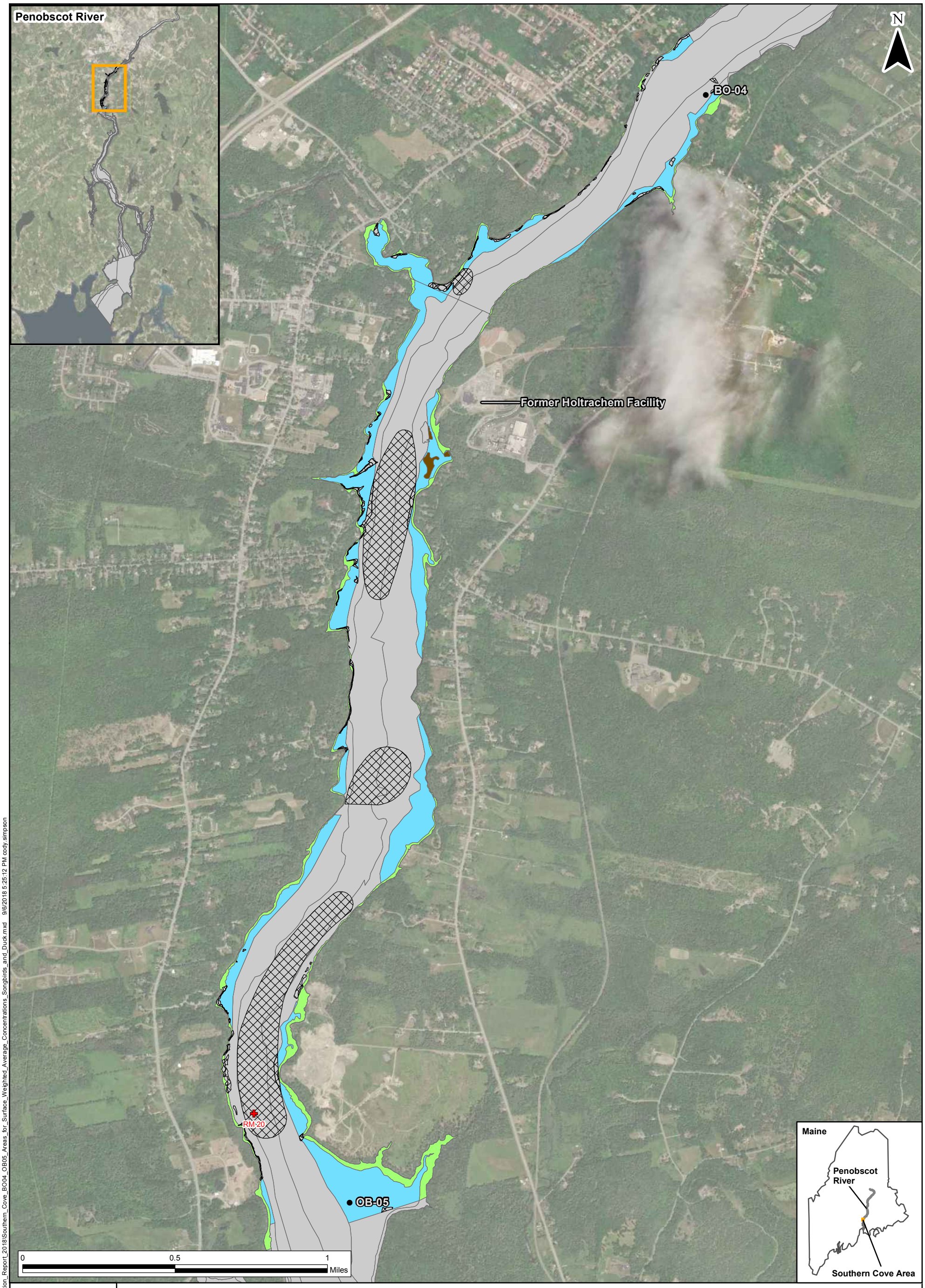

Legend

- River Mile Marker
- Biota Sampling Location
- Intertidal Area
- Wetland Area
- Southern Cove Excavation Footprint
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-6
Areas Used for the Development of Surface Area Weighted Average Concentrations - Southern Cove (Birds)

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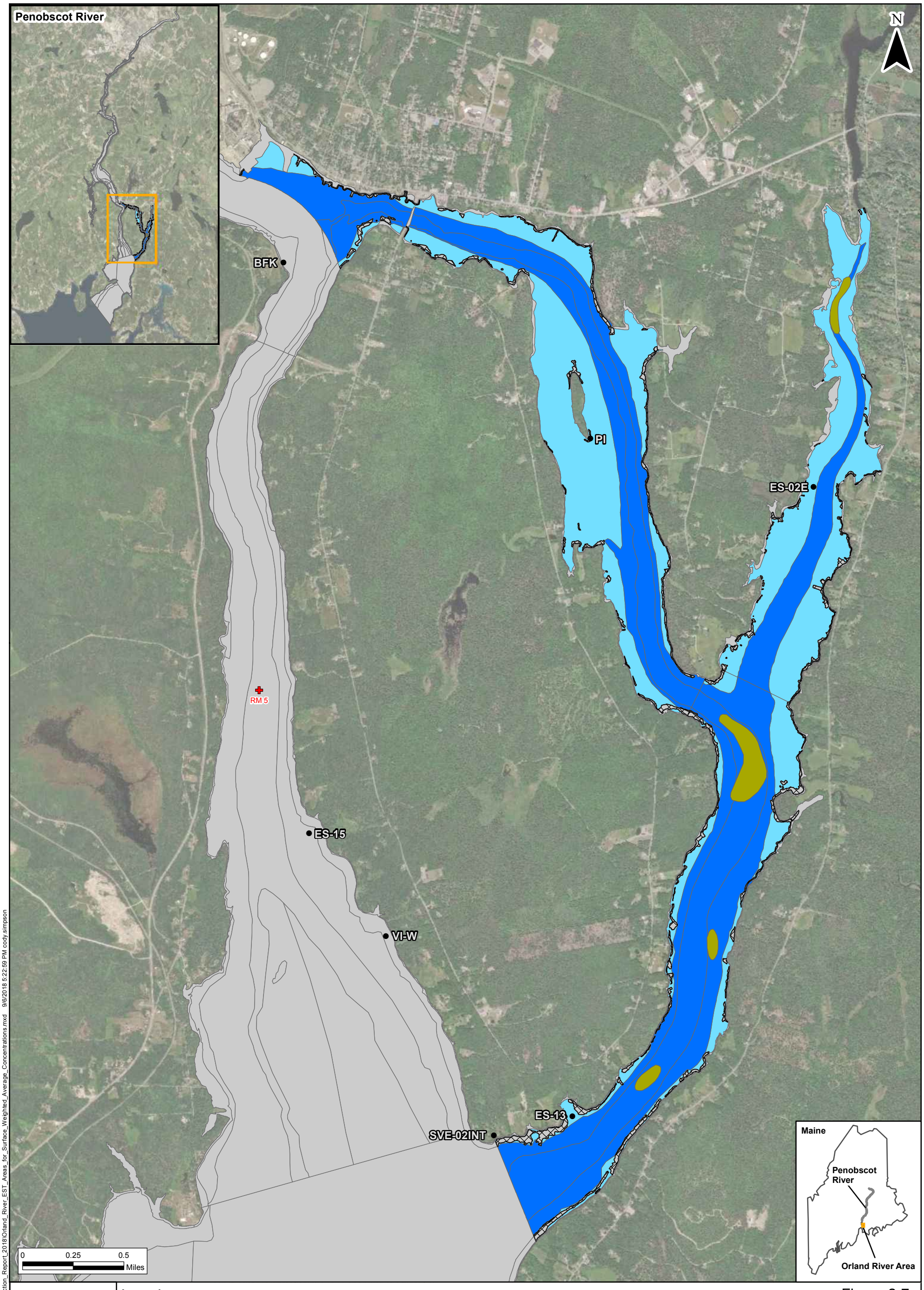

Legend

- River Mile Marker
- Biota Sampling Location
- Subtidal Area
- Intertidal Area
- Surface Deposit Ribbons
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-7
Areas Used for the Development of Surface Area Weighted Average Concentrations - Orland River and East Channel (Fish)

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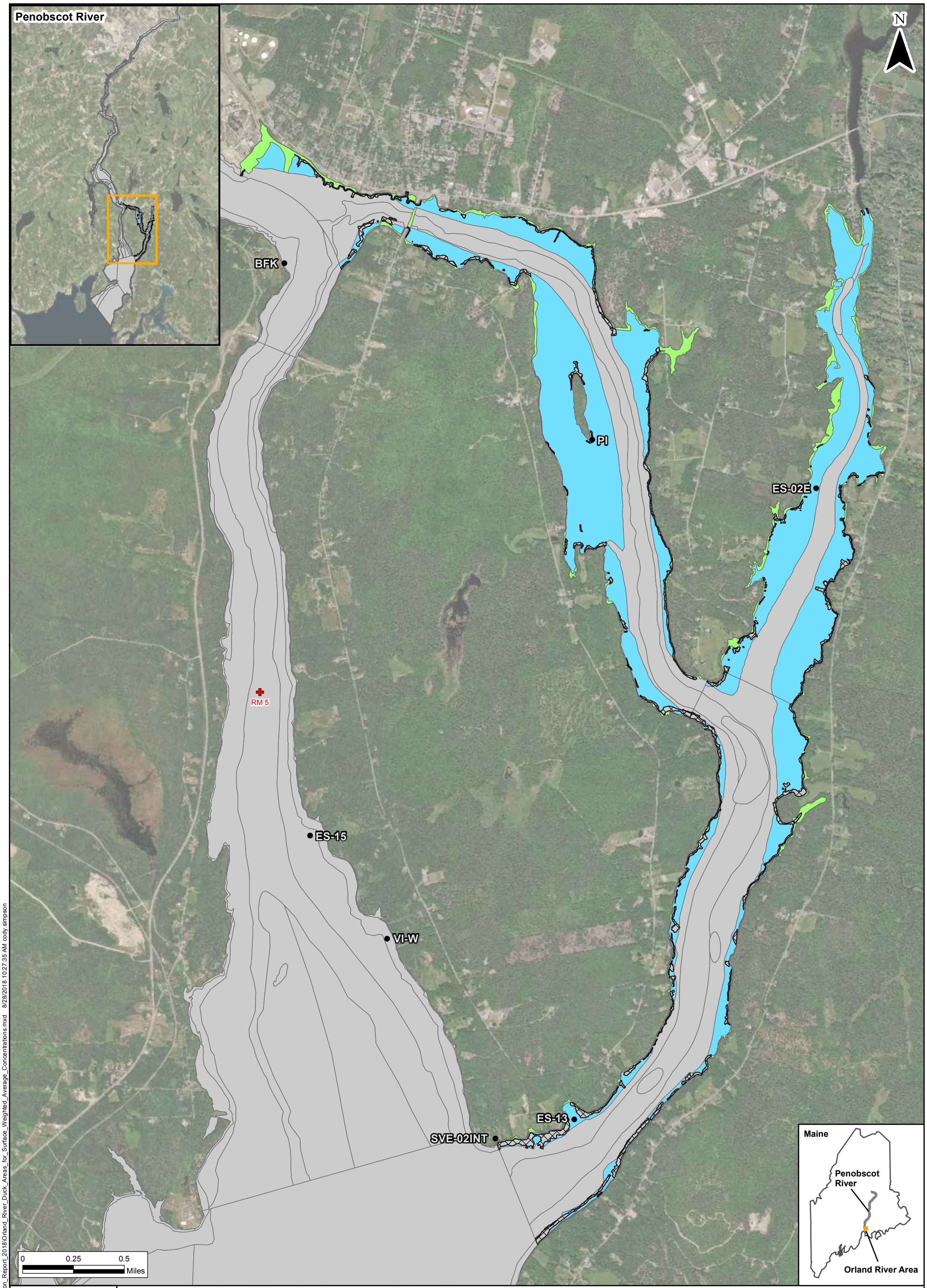

Legend

- River Mile Marker
- Biota Sampling Location
- Intertidal Area
- Wetland Area
- Reach Ribbons (Area Not Evaluated for Receptor)
- Bedrock and/or Boulders Not Included in SWAC Calculation

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Figure 2-8
Areas Used for the Development of Surface Area Weighted Average Concentrations - Orland River and East Channel (American Black Duck)

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Figure 3-1
Conceptual Exposure Model – Human Receptors

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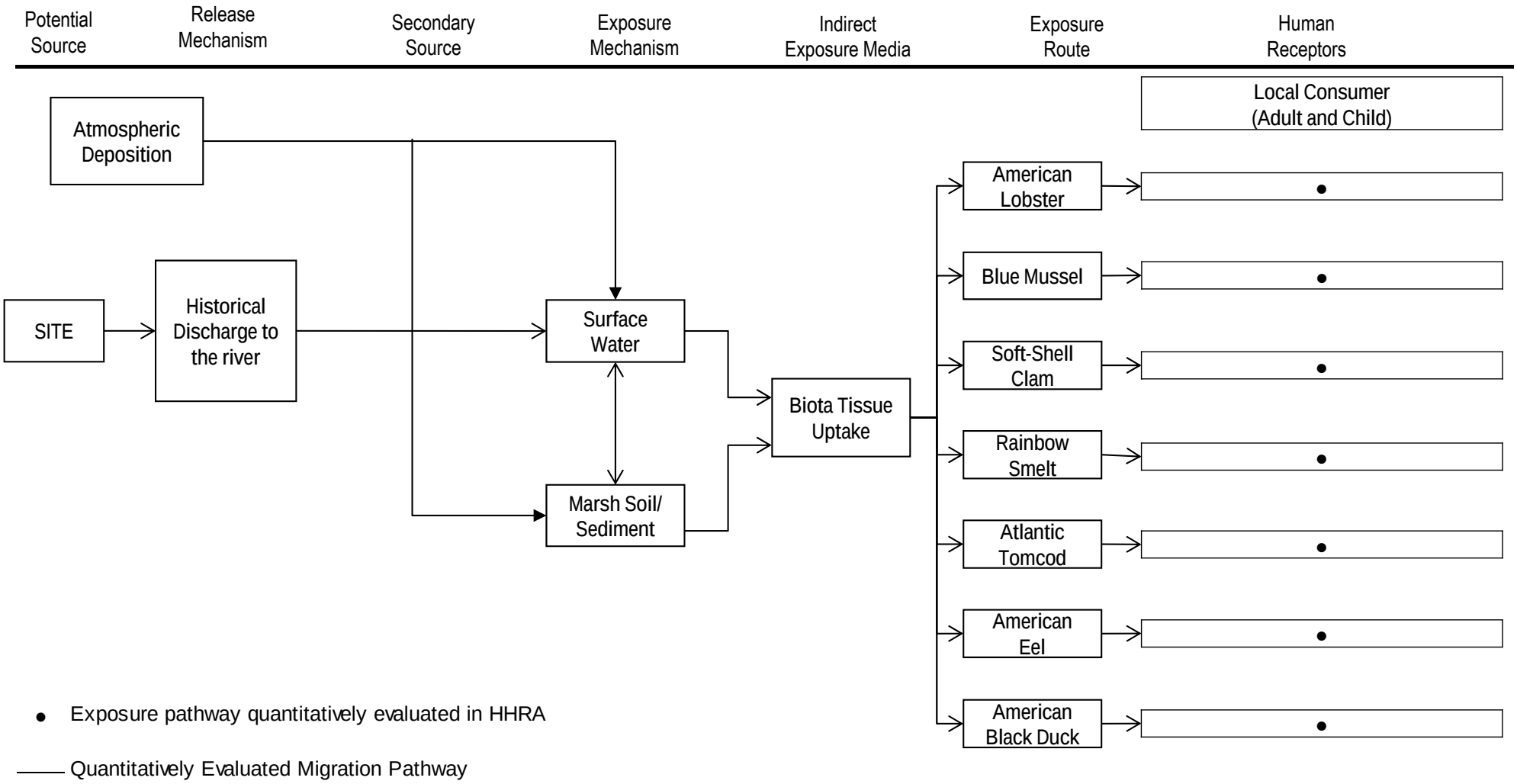

Prepared by: IMR 08/29/18
Checked by: LMS 08/29/18

Figure 4-1
Conceptual Exposure Model – Ecological Receptors

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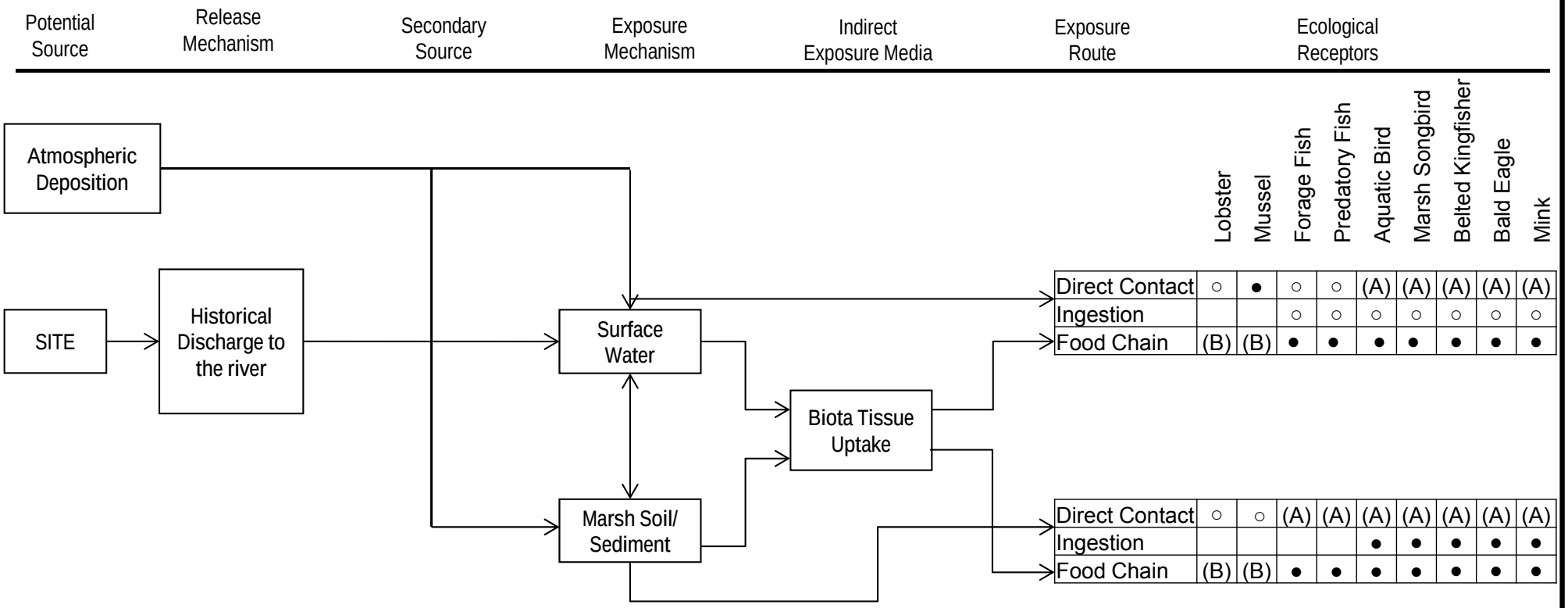

- ● Exposure pathway quantitatively evaluated in BERA
- ○ Exposure pathway potential occurs but not quantitatively evaluated in BERA
- (A) Direct contact with media not traditionally assessed in BERA
- (B) Tissue Uptake quantitatively evaluated in BERA
- —— Quantitatively Evaluated Migration Pathway

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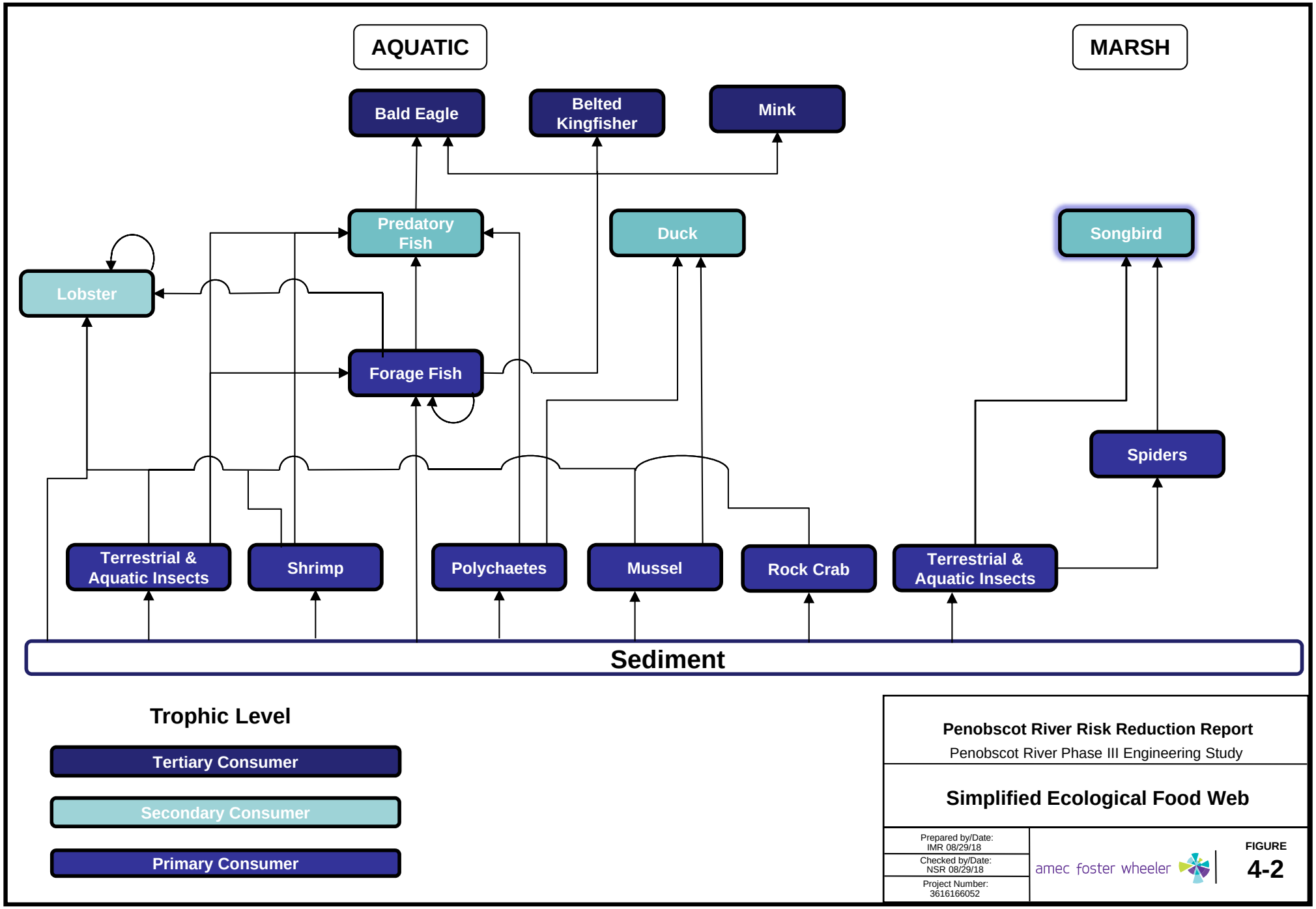
Checked by: NSR 08/29/18



Penobscot River Risk Reduction Report

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Simplified Ecological Food Web

Prepared by/Date: IMR 08/29/18	amec foster wheeler
Checked by/Date: NSR 08/29/18	FIGURE 4-2
Project Number: 3616166052	