UPPER 9-MILE SOURCE CONTROL INTERIM REMEDY FEASIBILITY STUDY

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
ARAR	applicable or relevant and appropriate requirement
BERA	baseline ecological risk assessment
BMP	best management practice
CAD	confined aquatic disposal
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CFT	Contaminant Fate and Transport (model)
COC	chemical of concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CPG	[Lower Passaic River] Cooperating Parties Group
CS 37	Conditional Simulation 37
CSM	conceptual site model
CSO	combined sewer overflow
CSTAG	Contaminated Sediments Technical Advisory Group
CTE	central tendency exposure
cy	cubic yard
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
DDx	DDT and its metabolites
DMU	dredge management unit
ENR	enhanced natural recovery
EPA	U.S. Environmental Protection Agency
FFS	focused feasibility study

FS	feasibility study
ft	foot/feet
GRA	general response action
GSR	green and sustainable remediation
HHRA	human health risk assessment
HMW	high molecular weight
HST	Hydrodynamic/Sediment Transport (model)
in.	inch(es)
IR	interim remedy
LMW	low molecular weight
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
mg/kg	milligrams per kilogram
MNR	monitored natural recovery
NCP	National Oil and Hazardous Substances Pollution Contingency Plan (also known as the National Contingency Plan)
ng/kg	nanograms per kilogram
NJDEP	New Jersey Department of Environmental Protection
O&M	operation and maintenance
OCC	Occidental Chemical Corporation
OLEM	Office of Land and Emergency Management
OMB	U.S. Office of Budget and Management
OMM	operations, maintenance, and monitoring
OU	operable unit
PAC	powdered activated carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PDI	pre-design investigation
ppm	parts per million
ppt	parts per trillion

PRG	preliminary remediation goal
RAL	remedial action level
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RG	remediation goal
RI/FS	remedial investigation and feasibility study
RM	river mile
RMC	residual management cover
RME	reasonable maximum exposure
RNA	regulated navigation area
ROD	record of decision
Settlement Agreement	May 2007 Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (CERCLA Docket No. 02-2007-2009) and associated statement of work
ST	Sediment Transport (model)
SWAC	surface area-weighted average concentration
SWO	stormwater outfall
TBC	to be considered
TCDD	tetrachlorodibenzo-*p*-dioxin
TCLP	toxicity characteristic leaching procedure
TEQ	toxicity equivalence
TI waiver	technical impracticability waiver
Tierra	Tierra Solutions, Inc.
TSCA	Toxic Substances Control Act
USACE	U.S. Army Corps of Engineers

EXECUTIVE SUMMARY

The Lower Passaic River Study Area (LPRSA) includes the Lower Passaic River (LPR) from Newark Bay to Dundee Dam (Figure ES-1). The LPRSA Cooperating Parties Group (CPG) has prepared a Source Control Interim Remedy (IR) Feasibility Study (FS) pursuant to the May 2007 Administrative Settlement Agreement and Order on Consent and as modified by a U.S. Environmental Protection Agency (EPA) October 10, 2018, letter to the CPG. The October letter directed the CPG to draft an FS for a potential source control IR for the upper 9 miles of the LPRSA, which extends from River Mile (RM) 8.3, at the confluence with the Second River, to Dundee Dam.

The IR FS develops and evaluates five source control IR alternatives for the upper 9 miles of the LPRSA, including a No Action alternative. A selected source control IR would support adaptive management of remedial actions in the LPRSA. Under the Adaptive Management Implementation Approach developed as part of the IR FS,[1] the design and implementation of an IR, followed by post-IR recovery assessment monitoring, would identify and reduce critical uncertainties associated with IR implementation, systematically incorporate new information, and provide a framework for future remedial action decisions. Adaptive management would begin during the remedial design, continue through IR implementation and a period of post-IR recovery assessment monitoring, and ultimately lead to the determination of final remediation goals (RGs) and the selection of a risk-protective final remedy in a final Record of Decision (ROD).[2]

RATIONALE FOR A SOURCE CONTROL INTERIM REMEDY

The rationale for a source control IR is supported by the conceptual site model (CSM) for the upper 9 miles. The CSM was derived from remedial investigation (RI) data and evaluations of contaminant distributions, sediment characteristics, and sediment and contaminant fate and transport. Based on the CSM, source sediment is defined in this IR FS as sediment having elevated concentrations. This sediment has a low potential for recovery, and acts as a reservoir for potential migration of contamination to surface water and biota,[3] thereby inhibiting overall recovery in the system. Sediment with low recovery potential is defined as that with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) and/or total polychlorinated biphenyl (PCB)

[1] The Adaptive Management Implementation Approach for the LPRSA is presented in Appendix D of this IR FS.
[2] It is anticipated that the final ROD would address all remaining site risks for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA.
[3] Concentrations in surface sediment represent an exposure to biota. Because the specific relationship between sediment concentrations and tissue concentrations is not certain, it is not certain whether contaminant concentrations in biota would be reduced in direct proportion to the reductions in sediment concentrations. However, it is expected that ecological exposure and tissue concentrations would be reduced over some time frame in response to an IR, which is expected to result in a reduction in ecological and human health risk.

concentrations greater than those associated with current water column particulate concentrations. Water column particulates influence system recovery through transport and deposition. Addressing source sediment would greatly reduce the 2,3,7,8-TCDD and total PCB surface area-weighted average concentrations (SWACs) (and reduce SWACs for other collocated contaminants that are addressed by the remediation footprint), which would in turn reduce concentrations on suspended water column particulates, reduce concentrations in surface sediment where water column particulates are deposited, reduce sources to biota, and accelerate system recovery.

Implementation of a source control IR would provide several expected benefits: a greater than 90 percent reduction in the average surficial sediment concentration of 2,3,7,8-TCDD,[4] the primary contaminant causing risk to human health; an anticipated significant reduction of ecological risk; and better alignment of remedial activities between the upper 9 miles and the lower 8.3 miles of the LPRSA. Remediation in both reaches of the river within a similar time frame would accelerate overall risk reduction and recovery for the entire LPR. In addition, an alignment of construction schedules for the two reaches would be expected to shorten the duration of the overall construction impacts on the community and the LPR system, and may allow opportunity to share resources (e.g., a sediment processing facility) for increased efficiency.

The Adaptive Management Implementation Approach presented in Appendix D of the IR FS was developed to guide the remediation of the upper 9 miles of the LPRSA under a multistep process. Consistent with the goals of EPA's Superfund program, the overall objective of adaptive management for the LPRSA is to ensure the attainment of risk-protective conditions for the site as expeditiously and cost-effectively as possible. The first step of adaptive management would be the design and implementation of a source control IR. An IR would be followed by a period of recovery assessment monitoring to evaluate the response of the system to the source removal and track the recovery of sediment, the water column, and biota. Based on the results of the recovery assessment monitoring, EPA would issue a final ROD to establish risk-based RGs and specify any additional actions beyond the IR that may be needed to address remaining site risks and attain the RGs.

The Adaptive Management Implementation Approach presents a structured program for identifying key uncertainties that control the understanding and therefore the remediation of the upper 9 miles of the LPRSA. The data that would be collected prior to, during, and following an IR would guide the planned multistep remedial action for the upper 9 miles. The outcome of the process would answer the critical overarching question:

[4] Surface concentration reductions can be assessed against current conditions, but, because risk-based cleanup goals for surface sediment in the upper 9 miles have not yet been determined, the benefit or significance of the surface concentration reduction relative to acceptable risk concentrations protective of human health and the environment cannot be assessed in the IR FS.

What actions are required to promote and attain the overall protection of human health and the environment, initially for the upper 9 miles of the LPRSA and subsequently for the entire LPRSA?

Incorporating structured adaptive management into the remediation of the upper 9 miles would ensure that data collected during the multiple monitoring activities of the project would be used to systematically incorporate new information, reduce site uncertainties, support effective decision-making under a structured framework, and establish an efficient and protective final remedy for sediment in the upper 9 miles and for surface water throughout the LPRSA. Specific components of the Adaptive Management Implementation Approach that support remediation of the upper 9 miles include IR design and implementation, system response to an IR, and system recovery to risk-protective conditions.

KEY FINDINGS FROM THE REMEDIAL INVESTIGATION

The LPR is the tidally influenced portion of the Passaic River that begins at Dundee Dam and ends at Newark Bay (Figure ES-2). The LPRSA is located within one of the major centers of industrialization and urbanization in the United States. The LPRSA became the focus of investigations because 2,3,7,8-TCDD, a by-product of the manufacture of Agent Orange, dichlorodiphenyltrichloroethane (DDT), and other chemicals were discharged from the former manufacturing facility at 80 and 120 Lister Avenue. The Lister Avenue facility is located at RM 3.4 in Newark, New Jersey.

In addition to 2,3,7,8-TCDD and DDT, other chemicals—including total PCBs, mercury, chlorinated pesticides, heavy metals, and polycyclic aromatic hydrocarbons (PAHs)—have been found in the sediment, water column, and biota of the LPR and were characterized in the RI. The primary human health risk drivers for the LPRSA are 2,3,7,8-TCDD and total PCBs (both of which are also among the ecological risk drivers), and these contaminants are the primary focus of the IR FS. All preliminary chemicals of concern (COCs) identified in the baseline human health risk assessment (HHRA) and baseline ecological risk assessment (BERA) (Tables ES-1 and ES-2) will be considered during the pre-design investigation, the long-term monitoring approach that supports the final remedy, and the final remedy.

Nature and Extent of Contamination in the Upper 9 Miles

In the upper 9 miles of the LPR, concentrations of 2,3,7,8-TCDD and total PCBs generally correlate with sediment type, specifically with higher concentrations tending to be found in fine sediment, although the range of concentrations is large. Sediment with the highest concentrations of 2,3,7,8-TCDD and total PCBs was deposited in the 1960s when the use and/or production of these chemicals were at their highest.

Surface sediment concentrations from RM 8 to RM 14[5] are characterized by large variability, with 2,3,7,8-TCDD ranging from less than 1 nanogram per kilogram (ng/kg) to a maximum of 51,100 ng/kg and total PCBs ranging from less than 0.01 milligram per kilogram (mg/kg) to a maximum of 33.9 mg/kg. Many of the high concentrations are found on point bars formed along the inner bends of the LPR at RM 8.5, RM 10.1, and RM 10.9. Point bars such as those that formed at RM 10.1 and RM 10.9 generally have higher surface sediment 2,3,7,8-TCDD concentrations in the central area of the point bar and lower concentrations in nearshore and offshore portions and in the navigation channel.

Upstream of RM 12, 2,3,7,8-TCDD concentrations generally decline, as do total PCB concentrations but to a lesser extent. 2,3,7,8-TCDD greater than 500 ng/kg and total PCBs greater than 1 mg/kg are confined mainly to fine sediment regions influenced by tidally driven net upstream transport from the lower river, which can extend to beyond RM 14 under very low flow conditions. The highest concentrations upstream of RM 14 are found in the silt and sand deposit at the first (upstream) oxbow at RM 14.5, reflective of the finer sediment there. Outside of the fine sediment deposits, concentrations above RM 12 are mostly less than 100 ng/kg for 2,3,7,8-TCDD and 1 mg/kg for total PCBs. Surface sediment concentrations upstream of RM 14.6 are less than 1 ng/kg for 2,3,7,8-TCDD and 0.5 mg/kg for total PCBs, reflecting the coarse sediment there and the lower concentrations originating from upstream of Dundee Dam.

The concentration patterns for DDT and its metabolites (total DDx) and mercury tend to mirror those of 2,3,7,8-TCDD in the region downstream of RM 14. Patterns of PAHs vary from those of the other contaminants, with no clear difference between concentrations in fine and coarse sediment. Upstream of RM 14, none of these contaminants show the dramatically lower concentrations evident for 2,3,7,8-TCDD because of the influence of sources upstream of Dundee Dam on sediment concentrations.

Summary of the Baseline Human Health and Ecological Risk Assessments

The baseline HHRA was performed to identify unacceptable risks to human health in the LPRSA. The baseline HHRA evaluated a range of potential receptors (child and adult anglers, swimmers, waders, boaters, and workers) and exposure pathways (ingestion of fish and crab, direct contact with sediment and surface water). Exposures to accessible surface sediment, surface water, fish fillet tissue, and crab edible tissue were evaluated on a site-wide basis. Human health risk in the LPRSA is driven primarily by consumption of fish and crab containing 2,3,7,8-TCDD, and to a lesser extent total PCBs (Table ES-1). Direct exposures to surface water and sediment do not pose risks in excess of the National Contingency Plan (NCP)

[5] These RMs use the RI system for consistency with that report. Elsewhere in the FS, the RMs are based on the USACE RM system. An approximate conversion to USACE RMs is to add 0.3 to the RI RMs; the exact conversion varies from 0.2 to 0.3 along the river.

cancer risk range of 10^{-6} to 10^{-4} or noncancer hazard index of 1, with the possible exception of accessible surface sediment in the RM 6 to RM 9 reach (particularly the East Bank). Upstream and regional levels of several preliminary COCs, including pesticides and mercury, are elevated and may contribute similar risks to the LPRSA. Risks from total PCBs above Dundee Dam were about one-third the risks for total PCBs in the LPRSA.

The objective of the BERA was to identify unacceptable risks posed by site-related chemicals to ecological receptors in the LPRSA. Ecological receptors evaluated included benthic invertebrates, macroinvertebrates, molluscs, fish, birds, mammals, zooplankton, amphibians/ reptiles, and aquatic plants. The potential for unacceptable risk was assessed using empirical and modeled data collected from a variety of chemical and biological sampling events and surveys conducted as part of the LPRSA RI. Unacceptable ecological risks are primarily driven by exposure to polychlorinated dibenzo-*p*-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), PCBs, and total DDx (Table ES-2). An evaluation limited to just the upper 9 miles of the LPR resulted in the same list of ecological risk drivers as in the BERA for the entire LPRSA. While there are statistically significant relationships between observed benthic community impairment and sediment chemistry/habitat conditions, the statistical relationships for individual contaminants are not strong.

Conceptual Model of Natural Recovery in Surface Sediment in the Upper 9 Miles

Natural recovery of surface sediment in the upper 9 miles of the LPR occurs principally as a result of water column particles with lower concentrations of COCs depositing on and burying and/or mixing with surface sediment (or by diluting surface sediment via cyclical erosion and deposition). The rate of recovery is likely controlled by net erosion of higher concentration sediment and cyclical erosion–deposition that brings higher subsurface concentrations into the surface layer.

Because net COC flux is directed from higher to lower concentration, sediment that has concentrations higher than those found on particles depositing from the water column is a net source of contaminants to the water column. Therefore, remediating sediment with COC concentrations higher than the concentrations on the particles depositing from the water column will significantly reduce concentrations on those depositing particles and accelerate concentration reductions in the remaining sediment. This higher concentration sediment is considered source sediment.

Sediment and surface water data collected during the RI and post-remediation data collected in the RM 10.9 removal action area suggest reasonable thresholds for classifying source sediment are 2,3,7,8-TCDD concentrations above the range of 200 to 400 ng/kg and total PCBs above 1 mg/kg. Targeting source sediment between RM 8.3 and RM 15 would achieve source control and accelerate recovery.

REMEDIAL ACTION OBJECTIVES

Remedial action objectives (RAOs) briefly describe what a remedial action under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) is expected to accomplish, taking into account the scope and goals of the CERCLA program, legal and administrative requirements (applicable or relevant and appropriate requirements [ARARs]), risks evaluated at the site, and background concentrations of contaminants in the environment. The overall goal of an IR for the upper 9 miles of the LPRSA is to control the most significant sediment sources of 2,3,7,8-TCDD and total PCBs above RM 8.3.[6] In doing so, an IR would address high contaminant concentrations (and reduce average contaminant concentrations) of these two contaminants, thereby eliminating the potential mobilization of elevated concentrations of the two contaminants to other areas of the LPRSA, accelerating recovery, and reducing exposure to biota.

Given that the IR FS compares source control alternative actions, and risk mitigation is not an explicit goal of an IR, risk-based preliminary remediation goals have not been established in the IR FS. EPA's final determination of the ability of remedial actions to meet RGs for protection of human health and the environment and comply with ARARs will be made in the final ROD for the LPRSA.

RAOs for an IR for the upper 9 miles of the LPRSA were developed in conjunction with EPA, the New Jersey Department of Environmental Protection (NJDEP), and the CPG. The RAOs use the concept of SWACs to quantify overall contaminant concentrations in surficial sediment. For this FS, SWAC is an average contaminant concentration in the top 6 inches (in.) of sediment based proportionally on the surface area that each data point represents.

RAOs for the source control IR are as follows:

RAO 1—Addressing Surficial Sediment Source Areas

Control the sediment sources of 2,3,7,8-TCDD and total PCBs by remediating surface sediment source areas containing elevated concentrations, thereby reducing the SWACs of 2,3,7,8-TCDD and total PCBs from RM 8.3 to RM 15. Achieve a post-IR 2,3,7,8-TCDD SWAC from RM 8.3 to RM 15 of not more than 85 ng/kg, approximately an order of magnitude higher than the Operable Unit 2 (i.e., the lower 8.3 miles of the LPRSA) 2,3,7,8-TCDD sediment RG of 8.3 ng/kg, and achieve a post-IR total PCB SWAC from RM 8.3 to RM 15 that is at or below the established total PCB background concentration of 0.46 mg/kg.

[6] Mitigating site risks is not an explicit goal of an IR, but will be addressed in a final ROD for the LPRSA.

RAO 2—Addressing Subsurface Sediment Source Areas

Control subsurface sediment (sediment deeper than 6 in. below the sediment bed) from becoming a source of 2,3,7,8-TCDD and total PCBs by remediating sediment between RM 8.3 and RM 15 that has a demonstrated potential for erosion to expose subsurface concentrations above the defined subsurface remedial action levels (RALs) established for 2,3,7,8-TCDD and total PCBs.

THE REMEDIAL ALTERNATIVES

This IR FS develops and evaluates a set of remedial alternatives to address sediment sources in the upper 9 miles of the LPRSA. The EPA October 10, 2018, Direction Letter specifies that, at a minimum, alternatives will include alternatives to achieve post-remedy 2,3,7,8-TCDD SWACs of 65 ng/kg, 75 ng/kg, and 85 ng/kg. Pursuant to the Direction Letter, other remedial alternatives that reflect additional post-remedy SWACs may also be evaluated, and a fourth active alternative, to achieve a post-remedy 2,3,7,8-TCDD SWAC of 125 ng/kg, is included in the IR FS for comparative purposes. The set of IR FS remedial alternatives is as follows:

- Alternative 1: No action
- Alternative 2: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 85 ng/kg and incorporating a total PCBs RAL of 1 mg/kg
- Alternative 3: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 75 ng/kg and incorporating a total PCBs RAL of 1 mg/kg
- Alternative 4: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 65 ng/kg and incorporating a total PCBs RAL of 1 mg/kg
- Alternative 5: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 125 ng/kg.

Alternatives 2 to 5 are framed around differing SWAC targets for 2,3,7,8-TCDD, to compare the potential relative benefits of achieving a lower post-IR SWAC in terms of source control and recovery with the higher cost, longer duration, and greater short-term project impacts associated with larger remedial areas and greater removal volumes. The target post-IR SWAC for total PCBs is controlled by the established total PCB background concentration of 0.46 mg/kg, and the available data suggest that a total PCBs RAL of 1 mg/kg will result in a SWAC at or below this concentration. Alternative 5, which does not achieve the RAOs, is included to compare a smaller remedy defined only by a 2,3,7,8-TCDD SWAC target of 125 ng/kg with the other alternatives.

All of the alternatives incorporate previously conducted or currently planned LPRSA remedial actions: the completed Phase 1 removal action near the Lister Avenue site, the RM 10.9 time

critical removal action, and the planned lower 8-mile remedial action. Site-specific information, site-specific data, and, as necessary, assumptions regarding pending action were used to incorporate these remedial actions into the IR FS remedial alternatives.

The technical specifications of the remedial alternatives (e.g., footprints, volumes, construction durations) were developed in the IR FS using a representative base map of surface and subsurface sediment concentrations of 2,3,7,8-TCDD and total PCBs. This was developed using a geostatistical interpolation procedure known as conditional simulation to generate 100 equally probable maps of surface (0–0.5 foot [ft]) and subsurface (0.5–1.5 ft) concentration distributions of the LPR sediment bed. From these maps, a base map representing the central tendency of the 100 maps was selected and used to delineate remedial footprints needed to meet the specifications of each IR FS alternative.

A summary of the main elements of each IR alternative is provided in Table ES-3, and a summary of the estimated cost of each IR alternative is presented in Table ES-4.

SUMMARY OF THE DETAILED EVALUATION AND COMPARATIVE ANALYSIS OF THE ALTERNATIVES

Each alternative was evaluated according to the remedy evaluation criteria specified by EPA in accordance with the NCP. Specific quantitative and qualitative metrics for each criterion were developed and used to support this evaluation in the IR FS. Quantitative metrics include a combination of metrics derived from the engineering specifications of the remedial alternatives and numerical model projections of the response of the LPR to the implementation of an IR.

Each IR alternative must meet two threshold criteria—overall protection of human health and the environment and compliance with ARARs—to be eligible for selection as EPA's preferred alternative. Five balancing criteria are then applied as a framework to assess tradeoffs among the long-term effectiveness and permanence; reduction in contaminant toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost of each alternative. The final two criteria address state and community acceptance. These are considered modifying criteria and are assessed by EPA, subsequent to the IR FS, based on consideration of state and public comment on EPA's proposed plan for remedial action.

Each alternative was evaluated individually against the NCP threshold and primary balancing criteria. In addition, a comparative analysis was conducted to assess the relative performance of the alternatives against each of the NCP criteria. A summary of the comparative analysis of alternatives is provided in Table ES-5.

Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 1 (No Action) fails to provide overall protection of human health and the environment because it does not achieve the RAOs and does not accelerate the recovery of sediment and water column COC concentrations. This alternative was retained in the IR FS for comparison with the other alternatives, as required by CERCLA.

Alternatives 2, 3, and 4 meet the IR FS metrics for overall protection of human health and the environment, with the ability to achieve the source control goals established in the RAOs and to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations.

Alternative 5 would promote accelerated recovery of sediment and water column COC concentrations, but not to the same degree as Alternatives 2, 3, or 4, and would not achieve the RAOs. This alternative was retained in the IR FS for comparison with the other alternatives to compare the performance of a smaller remedy defined only based on a 2,3,7,8-TCDD SWAC target with the other alternatives, as agreed upon between EPA, NJDEP, and the CPG.

Compliance with ARARs

All five alternatives have the ability to comply with ARARs.

Primary Balancing Criteria

While all of the remedial alternatives are evaluated against the primary balancing criteria in the IR FS, the remainder of this summary compares only the alternatives that meet the threshold criteria (i.e., Alternatives 2, 3, and 4).

Long-term Effectiveness and Permanence

Alternatives 2, 3, and 4 achieve a high degree of performance in long-term effectiveness and permanence. All three of these alternatives provide source control that will reduce concentrations in the water column and promote accelerated recovery in the unremediated areas of the sediment bed. The RALs for 2,3,7,8-TCDD and total PCBs resulting from the remedial footprints for Alternatives 2, 3, and 4 are within or below the target concentrations that are expected to support recovery and achieve source control in the upper 9 miles (i.e., a range of 200 to 400 ng/kg for 2,3,7,8-TCDD and equal to 1 mg/kg for total PCBs). The additional sediment targeted under Alternatives 3 and 4 is progressively coarser than deposits in the LPR classified as fine sediment and associated with high concentrations of 2,3,7,8-TCDD and total PCBs, indicating that the additional volume of sediment addressed by the larger alternatives (particularly Alternative 4) includes sediment that may not be source material and may be subject to natural recovery.

Once the RAOs have been achieved, the outcomes of an IR would include reduced human and ecological exposures to contaminants, reduced contaminant transport potential, and accelerated recovery of the remaining sediment and the water column. Alternatives 2, 3, and 4 would result in post-IR SWACs that represent approximately 91 to 94 percent reductions for 2,3,7,8-TCDD and approximately 81 to 84 percent reductions for total PCBs, compared with the pre-IR estimated SWACs.[7] The degree of SWAC reduction for Alternatives 2, 3, and 4 relative to pre-IR estimated SWACs varies by less than 3 percent among these alternatives.

All three alternatives provide effective source control and accelerate recovery, based on key source control metrics assessed over the 10-year period following the IR in the numerical model projections. These include projections of average sediment concentrations and recovery half-life, average water column concentrations, average and cumulative water column contaminant loads, average gross and net contaminant erosional flux (a measure of contaminant source strength), and contaminant concentrations on depositing fine sediment. Model projections are presented in the IR FS as ranges, to characterize the uncertainty in the projections. These projections show improvements in recovery potential, compared to the No Action alternative, for the active alternatives; the improvements are similar overall for Alternatives 2, 3, and 4. The additional sediment removal under the larger alternatives is not projected to increase the rate of post-IR recovery in comparison to Alternative 2, based on the significant overlap of the ranges of contaminant SWAC half-life for Alternatives 2, 3, and 4.

The additional remediation needed to reach lower target 2,3,7,8-TCDD SWACs under Alternatives 3 and 4 compared with Alternative 2 provides substantially lower relative benefit for other key source control metrics, including projected gross erosional flux, water column contaminant load, and contaminant concentrations on depositing fine sediment. For example, although Alternative 4 would provide 25 percent more in initial 2,3,7,8-TCDD SWAC reduction in comparison to Alternative 2 (which results in a post-IR SWAC below the RAO 1 target), it would result in reductions of only approximately 5 to 10 percent for the other metrics. Alternative 3 would provide 13 percent more in initial 2,3,7,8-TCDD SWAC reduction in comparison to Alternative 2 and would result in reductions of only approximately 4 to 9 percent for the other metrics. These results indicate that increasing the size of the remedial footprint to attain a lower SWAC target is comparatively inefficient in terms of reduced contaminant source strength, reduced recontamination potential, and increased recovery potential. The same finding holds for total PCBs, in which case the efficiency is even lower.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 2, 3, and 4 would use two treatment components to reduce the toxicity and mobility of contaminants through treatment: *ex situ* solidification/stabilization during

[7] SWAC comparisons are based on initial SWAC estimates of 932 ng/kg for 2,3,7,8-TCDD and 1.5 mg/kg for total PCBs, based on geostatistical evaluation, specifically Conditional Simulation 37 mapped to the model grid (see IR FS Appendix C).

processing of dredged sediment to support disposal and *in situ* sequestration via capping. The degree to which these reductions are achieved are proportional to the volume and mass removed and cap footprint, with the larger-footprint alternatives ranking incrementally higher than the ones with smaller footprints.

For Alternatives 2, 3, and 4, the estimated mass removed in the upper 2.5 ft of the sediment bed from RM 8.3 to RM 15 ranges from 590 to 630 g of 2,3,7,8-TCDD and 810 to 860 kg of total PCBs (Table ES-5), equating to increases of approximately 3 and 7 percent for Alternatives 3 and 4, respectively, compared to Alternative 2. The small additional mass removal for Alternatives 3 and 4 compared to Alternative 2 reflects the incrementally lower concentrations in the additional sediment that would be removed under the larger alternatives.

Short-Term Effectiveness

Alternatives 2, 3, and 4 would result in short-term worker risks and community impacts proportional to the construction duration. Alternative 2, which has the smallest remedial footprint and the shortest estimated construction duration, would have the least short-term impacts on risks to workers, communities, and the ecosystem. Conversely, Alternative 4, the alternative with the largest remedial footprint and longest estimated construction duration, would have the largest short-term impacts. For example, Alternative 2 would require an estimated 670 barge trips to transport dredged sediment,[8] compared with 716 and 778 barge trips required by Alternatives 3 and 4, respectively, or 7 and 16 percent additional barge trips, respectively. Short-term impacts to workers and the community are proportionally greater with the larger footprints associated with Alternatives 3 and 4, compared with Alternative 2. Construction of Alternative 2 would require an estimated 448,639 worker hours,[9] compared with 476,899 and 509,681 worker hours required by Alternatives 3 and 4, respectively, or 6 and 14 percent additional worker hours, respectively.

A Green and Sustainable Remediation evaluation showed that impacts (greenhouse gas emissions, total energy used, water consumption, and potential injuries) are proportional to remedy size; the smallest remedial footprint has the smallest impacts, and impacts increase with increasing size of remedial footprints. Resuspension and upstream and downstream transport of contaminants during construction are projected to be similar for Alternatives 2, 3, and 4.

Implementability

The implementation of an IR in the upper 9 miles of the LPRSA would present a range of challenges due to the urban environment. Specific challenges that would need to be considered during remedial design and implementation include dredging constraints posed by utility crossings, existing shoreline structures, in-water bridge structures, and hard river bottom. The transport of materials up and down the LPR would also present implementability challenges

[8] Assuming a 500 cy barge.
[9] Assuming an average work crew of 30 workers per day.

due to low clearance and/or narrow bridges, which could necessitate custom or specialized equipment for passage and frequent bridge openings proportionate to the number of projected barge trips for each alternative, to allow barges and tugs to pass. As evidenced during the RM 10.9 and Phase 1 removal actions, inoperable bridges resulted in significant construction delays.

While the alternatives can be designed to address these implementability challenges, all of these challenges are anticipated to be significant, and most would increase in proportion to the size of the remedial footprint and the construction duration, and therefore would be larger for Alternative 3 compared with Alternative 2, and larger for Alternative 4 compared with Alternatives 2 and 3. For example, designing and implementing the remedy where the footprint abuts hardened or engineered shoreline could require significant effort to avoid damaging engineered shoreline structures or to rebuild or replace failing structures, and/or result in lower production rates or unanticipated delays. Alternative 2 abuts an estimated 37,792 linear feet of hardened shoreline, compared with 39,551 and 41,454 linear feet abutted by Alternatives 3 and 4, respectively, or 5 and 10 percent additional hardened shoreline, respectively.

Cost

A summary of the estimated cost for each IR alternative is presented in Table ES-4. Net present value costs for the alternatives that achieve the threshold criteria (Alternatives 2, 3, and 4) range from $420 million to $468 million. Costs that are assumed to be the same for the active alternatives include the pre-design investigation and remedial design, long-term monitoring, and periodic sediment sampling. Other costs vary with area, volume, and construction duration. The cost estimate assumes that long-term monitoring and maintenance will occur over a 30-year period following completion of construction, including both recovery assessment monitoring following an IR and additional long-term monitoring to be specified when a final remedy is selected under a final ROD.

The estimated costs for the alternatives increase with remedial footprint size and removal volume. All three alternatives fully achieve the established RAOs for a source control IR, and the alternatives with larger remedial footprints are not projected to result in faster recovery rates following remedy completion. Together with the implementation of the lower 8-mile remedy, an IR in the upper 9 miles based on Alternative 2, 3, or 4 is expected to promote significant river-wide recovery, with the degree of overall recovery similar for all of these alternatives. Alternative 3 provides greater certainty than Alternative 2 of addressing the source material, thus accomplishing the IR source control objective, without going beyond and capturing areas that may be experiencing natural recovery, which are included in the Alternative 4 footprint.

CONCLUSION

Alternatives 2, 3, and 4 all meet the IR FS metrics for the threshold criteria:

- The ability to achieve the RAOs
- The ability to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations
- The ability to comply with ARARs.

The three alternatives achieve a high degree of long-term effectiveness and permanence (Table ES-5). All three of these alternatives provide source control that will reduce concentrations in the water column and promote accelerated recovery. The RALs for 2,3,7,8-TCDD associated with Alternatives 2, 3, and 4 are to varying degrees within or below the range of target concentrations that define source sediment. Alternative 2 ranks comparatively higher than Alternatives 3 and 4 for two critical balancing criteria—short-term effectiveness and implementability. Alternatives 3 and 4 provide slight increases of approximately 3 to 7 percent, respectively, in the reduction of toxicity, mobility, and volume through treatment compared with Alternative 2.

Considering cost with respect to overall effectiveness, the larger remedial footprints and additional costs of Alternative 3 (5 percent more in cost) and Alternative 4 (11 percent more in cost) compared with Alternative 2 do not provide significant additional benefit or efficiencies with respect to meeting the source control objectives of an IR. This lack of significant benefit or efficiency is more pronounced comparing Alternative 4 to Alternative 2 as opposed to comparing Alternative 3 to Alternative 2.

1 INTRODUCTION

This Source Control Interim Remedy (IR) Feasibility Study (FS) has been prepared as part of the Lower Passaic River Study Area (LPRSA) remedial investigation and feasibility study (RI/FS), which is being performed by the Lower Passaic River Cooperating Parties Group (CPG), in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and under the oversight of the U.S. Environmental Protection Agency (EPA). This IR FS is prepared in accordance with the EPA-approved work plan (Integral 2019).

The LPRSA comprises the Lower Passaic River (LPR) from Newark Bay to Dundee Dam (Figure 1-1). This IR FS is focused on the upper 9 miles of the LPRSA, from River Mile (RM) 8.3, at the confluence with the Second River, to the Dundee Dam.[10] The IR FS develops and evaluates source control IR alternatives for the upper 9 miles. If EPA proposes to implement one of the source control alternatives, it would be documented in a Proposed Plan, followed by a period of public comment and an interim Record of Decision (ROD). The IR would be implemented followed by a period of long-term monitoring[11] leading to a final ROD for sediment for the upper 9 miles and surface water for the entire LPRSA to memorialize a final remedial action decision to achieve final site cleanup. The IR FS includes an Adaptive Management Implementation Approach that describes how the upper 9 miles of the LPRSA would be managed throughout the IR to the final ROD and final remedy by addressing key project uncertainties and providing a structured framework for responding to new information and changing conditions during and subsequent to the IR in order to reach the overarching goal of attaining the overall protection of human health and the environment, initially for the upper 9 miles of the LPRSA and subsequently for the entire LPRSA.

[10] The IR FS primarily uses the RM system developed by the U.S. Army Corps of Engineers (USACE), which follows the navigation channel of the LPR. The RI of the LPRSA used an RM system that follows the geographic centerline of the river (which was developed by EPA and used for the RI evaluations), referred to as the RI RM system. RM 0 in the RI RM system is defined by an imaginary line between two marker lighthouses at the confluence of the LPR and Newark Bay: one in Essex County just offshore of Newark and the other in Hudson County just offshore of Kearny Point. River miles then continue upriver to Dundee Dam (at RM 17.4 in the RI RM system). RM 0 in the USACE system is just offshore of Kearney Point, and river miles continue upriver to the Dundee Dam, which is at RM 17.7 in this system. The two RM systems are about 0.2 to 0.3 miles apart (i.e., USACE RMs correspond roughly to RI RMs plus 0.2 to 0.3). In this document, USACE RMs have no prefix, while references to the RI RMs in this document are designated with the prefix RI or noted as the RI RM system.

[11] Long-term monitoring is assumed to occur for 30 years following IR implementation for costing purposes in the IR FS. Monitoring would occur in two phases, including a recovery assessment phase following IR completion and a subsequent phase following selection of a final remedy and issuance of a final ROD.

1.1 REGULATORY SETTING

The RI/FS work required by the May 2007 Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (CERCLA Docket No. 02-2007-2009) and associated statement of work (Settlement Agreement) is being conducted under CERCLA, as implemented through the regulatory requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (also known as the National Contingency Plan [NCP]) (40 Code of Federal Regulations [CFR] § 300.430). The CPG is implementing the RI/FS work in accordance with the 2007 Settlement Agreement, the associated statement of work (USEPA 2007, Appendix B), and the following planning documents:

- Lower Passaic River Restoration Project Work Plan (MPI 2005a)
- Lower Passaic River Restoration Project Field Sampling Plan, Volume 1 (MPI 2006)
- Lower Passaic River Restoration Project Draft Field Sampling Plan, Volume 2 (MPI et al. 2006)
- Lower Passaic River Restoration Project, Revised Preliminary Draft Field Sampling Plan, Volume 3 (MPI 2005b)
- Lower Passaic River Restoration Project, Quality Assurance Project Plan (MPI 2005c)
- Feasibility Study Work Plan, Upper 9-Mile Interim Remedy Addendum, Lower Passaic River Study Area Feasibility Study (Integral 2019).

In 2017, following issuance of the 2016 ROD for the lower 8.3 miles of the LPRSA (see Section 1.1.3), CPG initiated discussions with EPA on an IR for the upper 9-mile reach of the LPRSA, focused on source control. In February and March 2018, EPA's Contaminated Sediments Technical Advisory Group (CSTAG) conducted a review of the IR source control proposal (CPG 2018a); this review included stakeholder input from EPA, EPA's partner agencies, the LPR Community Advisory Group, and CPG. In an April 25, 2018, recommendation memorandum, CSTAG concurred that the central elements of the IR proposal are consistent with the 2017 Office of Land and Emergency Management (OLEM) Directive on Remediating Contaminated Sediments (OLEM Directive 9200.1-130). CSTAG expressed support for the February 2018 IR proposal in concept and provided 10 detailed recommendations to EPA Region 2 to strengthen both the goals and the framework of the IR proposal to better assure its success (USEPA 2018a). The CSTAG recommendations were used to guide improvements of the proposal and the development of the IR FS. EPA Region 2 responses to CSTAG recommendations (USEPA 2018b) were also addressed in the development of the IR FS. On October 10, 2018, EPA issued a Direction Letter, directing the CPG to complete the 17-mile RI and prepare an IR FS for the upper 9 miles, in accordance with the CPG proposal and subsequent EPA Region 2 and CSTAG comments (USEPA 2018c).

The IR FS process, and any potential response action selected based on the IR FS, must comply with CERCLA and be performed in a manner consistent with its associated guidance. The specific documents guiding the conduct of this IR FS for the LPRSA include:

- Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (USEPA 1988)
- A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents (USEPA 1999)
- A Guide for Developing and Documenting Cost Estimates during the Feasibility Study (USEPA 2000a)
- A Risk Management Strategy for PCB-Contaminated Sediments (NRC 2001).
- Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites (USEPA 2002)
- Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005)
- Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study and Statement of Work (USEPA 2007)
- Remediating Contaminated Sediment Sites – Clarification of Several Key Remedial Investigation/Feasibility Study and Risk Management Recommendations, and Updated Contaminated Sediment Technical Advisory Group Operating Procedures (USEPA 2017)
- Preparation of Feasibility Study Evaluating Interim Remedy Alternatives. Letter from Michael Sivak, USEPA Region 2 to the CPG (USEPA 2018c).

1.1.1 The Diamond Alkali Superfund Site

The LPRSA is part of the Diamond Alkali Superfund Site, which includes four operable units (OUs) (Figure 1-2). OU1 is the former Diamond Alkali Site at 80-120 Lister Avenue; OU2 includes the lower 8.3 miles of the LPRSA; OU3 encompasses Newark Bay; and OU4 addresses the entire LPRSA, including the upper 9 miles. In May 2007, EPA entered into the Settlement Agreement and Order on Consent (USEPA 2007) with CPG to complete the RI/FS for the LPRSA. The LPRSA RI report (AQEA 2019) provides a comprehensive study of environmental conditions, and human health and ecological risks, for the entire LPRSA.

1.1.2 CERCLA Early Removal Actions

Under a 2008 settlement agreement (USEPA 2008a) by and between EPA, Occidental Chemical Corporation (OCC) and Tierra Solutions, Inc. (Tierra), OCC and Tierra agreed to perform a sediment removal action adjacent to the Lister Avenue facility, consisting of the removal and

disposal of 200,000 cubic yards (cy) of LPR sediment. In July 2011, OCC (through Tierra) began construction activities, followed by the removal of 40,000 cy of the sediment containing the highest concentrations of dioxin in the LPR from a 2-acre area in the immediate vicinity of the Lister Avenue site (Phase 1). This removal, which was anticipated to be the first phase of the 200,000 cy removal action, was completed in December 2012 (Tierra 2013). The additional removal of 160,000 cy of LPR sediment from adjacent areas (Phase 2) has not been implemented to date. The agreement for Phase 2 of the Tierra removal contemplated the siting and use of a confined disposal facility (CDF) as a receptacle for the dredged materials. However, this has not occurred and may no longer be practicable. Because the approach for addressing the Phase 2 sediment has not been determined at this time, and the lower 8.3-mile remedial design is under way, EPA is integrating the Phase 2 area with the lower 8.3-mile remedy in a coordinated and consistent manner.

Under a settlement agreement executed on June 18, 2012, by and between EPA and CPG (USEPA 2012a), CPG agreed to fund and perform the removal and disposal of between 15,000 and 20,000 cy of sediment from an LPRSA mudflat at RM 10.9[12] (Figure 1-2). The objective of this work was to remove sediment with high concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), polychlorinated biphenyls (PCBs), and other chemicals of potential concern (COPCs), and cap in place remaining contaminated sediment to reduce the potential for exposure to receptors and to prevent potential migration of contamination from the RM 10.9 removal area. The RM 10.9 removal action, which was conducted under CERCLA authority as a time-critical removal action, was initiated in July 2013. The removal of a final volume of 16,050 cy of sediment was completed on October 3, 2013, followed by capping, which was completed on May 29, 2014 (CH2M Hill 2019).

1.1.3 Lower 8-Mile Remedial Action

In parallel with the ongoing work for OU4 being performed by the CPG under the 2007 Settlement Agreement, EPA performed a focused feasibility study (FFS) to address contaminated sediment in OU2 (i.e., the lower 8.3 miles of the LPRSA) (LBG 2014a). Following completion of the OU2 FFS, issuance and review of the proposed plan, EPA issued a ROD on March 3, 2016 (USEPA 2016a). The ROD-selected remedy was capping with dredging for flooding and navigation, which included dredging for placement of an engineered cap in the lower 8.3 miles, and partial reestablishment of the Federal Navigation Channel in the lower 1.7 miles. The lower 8.3-mile remedy addresses eight chemicals of concern (COCs): dioxins and furans (2,3,7,8-TCDD and TCDD toxicity equivalence (TEQ), total PCBs, total dichlorodiphenyltrichloroethane (DDT), dieldrin, total polycyclic aromatic hydrocarbons (PAHs), mercury, copper, and lead. OCC is performing the remedial design under an Administrative Order on Consent with EPA dated September 30, 2016 (USEPA 2016b). The

[12] The RM 10.9 removal action area was designated in the RI RM system. On Figure 1-2, which is in the USACE RM system, this area appears at RM 11.2.

lower 8.3-mile intermediate (60%) design report (Arcadis 2019) was issued in December 2019, and pre-design and construction design activities are ongoing. Mobilization for construction of the OU2 remedial action is scheduled to begin in 2021. Construction of an upland processing facility and a support facility is assumed to occur in 2021 to 2022. Dredging and associated in-river construction is assumed to commence on July 1, 2023, and finish by the end of 2029 (Arcadis 2019).

1.2 RATIONALE FOR A SOURCE CONTROL INTERIM REMEDY

The rationale for an IR focused on source control is supported by the conceptual site model (CSM) for the upper 9 miles derived from RI data and evaluations of contaminant distributions, sediment characteristics, and sediment and contaminant fate and transport behavior (Section 2.6). In summary, the CSM and supporting data and evaluations indicate that there are identifiable areas of sediment with contaminant concentrations sufficiently high to act as ongoing sources to the water column, biota, and the remainder of the sediment bed. Remediating these source areas would reduce exposure to biota, limit the potential for contaminant transport to other areas, and accelerate recovery of the water column and the unremediated areas of the sediment bed. Current data suggest that the source areas to be targeted by the potential IR are located between RM 8.3 and RM 15 (Figure 1-2). However, if sediment data collected between RM 15 and Dundee Dam that support the IR design identify high surface concentrations in the reach of RM 15 to Dundee Dam, these areas would be evaluated during remedial design to determine whether they constitute a source that is inhibiting the recovery of the LPR. If that determination is made and if it is feasible to address these areas in conjunction with the remediation to achieve the IR remedial action objectives (RAOs), then these areas would be addressed as part of the IR construction. A detailed discussion of the LPRSA CSM can be found in the RI report (AQEA 2019).

Implementation of a source control IR provides an opportunity to accelerate remedial actions in the upper 9 miles. This would likely result in better alignment of the timing of remedial activities in the upper 9 miles and in the lower 8.3 miles of the LPRSA. Remediation in both reaches of the river within a similar time frame can be expected to accelerate overall risk reduction and recovery of the 17 miles. In addition, an alignment of construction schedules for the two reaches may allow opportunity to share resources (e.g., a sediment processing facility) for increased efficiency.

An IR in the upper 9 miles of the LPRSA is consistent with EPA guidance (e.g., OLEM Directive 9200.1-130, USEPA 1999) as well as the principle established in the NCP that an IR should not be inconsistent with nor preclude implementation of an expected final remedy.

1.3 IR FS PROCESS

This IR FS identifies and evaluates a set of remedial alternatives to address sediment sources in the upper 9 miles of the LPRSA. It presents detailed and comparative analyses of the alternatives and lays the groundwork for proposing and selecting an IR that addresses the nine evaluation factors specified under the NCP (40 CFR § 300.430(e)(9)(iii)). After this IR FS is finalized, EPA will determine whether to select a preferred alternative and proceed with a source control IR. If so, EPA will issue a proposed plan for public review and comment. The proposed plan will summarize the results of the IR FS and describe the basis for EPA's identification of a preferred alternative. After comments on the proposed plan have been evaluated and addressed, it is anticipated that EPA will issue an interim ROD and Responsiveness Summary that documents the selected action and the basis for its selection. The interim ROD will document the selected source control IR, which, consistent with CERCLA guidance, will not be incompatible with nor preclude a final remedy (40 CFR §300.430(a)(1)(ii)(B)). EPA will select and memorialize a final remedy for the LPRSA, including establishment of final remediation goals compliant with CERCLA, in the final ROD for the LPRSA for sediment in the upper 9 miles and surface water throughout the LPRSA. EPA is anticipated to issue the final ROD following completion of the IR and a period of monitoring following IR completion under an adaptive management framework, to establish final remediation goals (RGs) and determine the basis and need for any further remedial action to address site-related risks.

1.3.1 Definitions for the Feasibility Study

Key terms that are used in this FS are defined in this section, along with appropriate regulatory citations, where applicable.

Applicable or relevant and appropriate requirements (ARARs) are promulgated federal and state standards, requirements, criteria, or limitations that are determined to be "applicable" or "relevant and appropriate" to a CERCLA response action. Under Section 121(d) of CERCLA, an applicable requirement is a promulgated federal or state standard that specifically addresses a hazardous constituent, remedial action, location, or other circumstance at a site. For a requirement to be applicable, its intended scope and authority must encompass the planned remedial actions and/or circumstances at a site. A relevant and appropriate requirement is a promulgated federal or state requirement that addresses problems or situations similar to those encountered at a site, even though the requirement is not legally applicable.

Preliminary remediation goals (PRGs) specify the estimated endpoint concentrations or risk levels, for each exposure pathway, that are believed to provide adequate protection of human health and the environment and comply with ARARs, based on available site information (USEPA 1991a,b, 1997). A PRG is a specific identification of a contaminant concentration or risk level in an environmental medium (e.g., sediment, water, or fish tissue), protective of human

health and/or the environment under a given exposure scenario. Final RGs would be stated in the final ROD and may differ from the PRGs based on selection of different target risk levels and/or exposure scenarios than were used in the development of PRGs, taking into consideration factors and trade-offs evaluated in the nine-criteria analysis under the NCP (USEPA 1999). As the purpose of a source control IR is to address higher contaminant concentrations that are source areas and not attain risk-based goals, and as the purpose of this IR FS is to develop and compare IR alternatives, PRGs are not developed in the IR FS. PRGs would be developed following an IR ROD, on a parallel track with the IR remedial design, and would be used to assess the future recovery of the system and inform a final ROD including final RGs.

Remedial action objectives (RAOs) provide a general description of what the proposed remedial or response action is expected to accomplish to address the risks presented at the site (USEPA 1999, 2005). They are narrative statements of the medium-specific or area-specific goals for protecting human health and the environment. RAOs are used to help focus development and evaluation of remedial alternatives. RAOs that specify the goals to be attained by a source control IR have been developed for the IR FS.

Remedial action levels (RALs) are chemical-specific sediment concentrations that are used to delineate areas where active remedial measures (e.g., dredging or capping) will be undertaken under a given remedial alternative. RALs are not the same as PRGs or final RGs, which define the ultimate risk-reduction or ARAR-based goals to be achieved through remedial action, and which are not always expressed as sediment concentration goals. RALs may differ among various remedial alternatives, reflecting different trade-offs among considerations of immediate risk reduction, longer-term recovery, remedy scale and implementability, and cost. RALs also may differ among different areas of a site, depending on the magnitude and type of risk to be addressed, land use, and the expected rate of future natural recovery. For the IR FS, RALs are identified to achieve the RAOs, and RALs would be refined using data from the pre-design investigation (PDI) during remedial design.

Surface area-weighted average concentrations (SWACs) are similar to a simple arithmetic average of point concentrations over a defined area, except that each individual concentration value is weighted in proportion to the sediment area it represents, thereby minimizing the influence of spatially biased sampling. SWACs have been used at several other CERCLA contaminated sediment sites (e.g., Fox River [WDNR and USEPA 2002] and Lower Duwamish Waterway [USEPA 2013a]) and may be used to evaluate reductions in sediment concentrations. In the IR FS, SWACs are the specific basis for one of the RAOs and are used to establish remedial footprints.

Source sediment is defined in this IR FS[13] as sediment having elevated concentrations. This sediment has a low potential for recovery, and acts as a reservoir for potential migration of contamination to surface water and biota,[14] thereby inhibiting overall recovery in the system. Sediment with low recovery potential is defined as that with 2,3,7,8-TCDD and/or total PCB concentrations greater than those associated with current water column particulate concentrations. Water column particulates influence system recovery through transport and deposition (additional information related to contaminant transport and the influence of depositing water column particulates on recovery is provided in Section 2.4.3 and Section 2.6, respectively). Addressing source sediment would greatly reduce the 2,3,7,8-TCDD and total PCB SWACs (and reduce SWACs for other collocated contaminants that are addressed by the remediation footprint), which would in turn reduce concentrations on suspended water column particulates, reduce concentrations in surface sediment where water column particulates are deposited, reduce sources to biota, and accelerate system recovery. If an IR is implemented, source sediment would be defined during design based on the selected target SWACs, pre-design sediment sampling data, and associated RALs.

Information sources **to be considered (TBC)** are non-promulgated criteria, advisories, guidance, and proposed standards issued by federal or state governments. TBCs are not potential ARARs because they are neither promulgated nor enforceable, although it may be necessary to consult TBCs to interpret ARARs or to determine PRGs when ARARs do not exist for particular contaminants or may not be sufficiently protective. Compliance with TBCs is not mandatory.

1.3.2 Feasibility Study Activities

The IR FS develops and evaluates a set of remedial alternatives to address sediment source areas in the upper 9 miles of the LPRSA. The activities described in the following sections were performed to support the development and analysis of the IR FS alternatives. The detailed approach to implementing these activities was established in a series of collaboration meetings with EPA, the New Jersey Department of Environmental Protection (NJDEP), and CPG that were held from October 2018 through completion of the draft IR FS; the framework for the IR and the basis for the IR FS were defined through this collaborative process.

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[13] This definition was developed for the IR FS to explain why certain sediment is targeted for removal, to support comparison of the source control alternatives, and to clarify the strategy and the rationale of the IR. A project-specific source definition aligns with the NCP (40 CFR 300.5) and existing EPA guidance in terms of identifying sources that are "…a release of contaminants from direct and indirect continuing sources to the water body under investigation" (USEPA 2005) and "…contaminants that act as a reservoir for ongoing migration and exposure (USEPA 1991c).
[14] Concentrations in surface sediment represent an exposure to biota. Because the specific relationship between sediment concentrations and tissue concentrations is not certain, it is not certain whether contaminant concentrations in biota would be reduced in direct proportion to the reductions in sediment concentrations. However, it is expected that ecological exposure and tissue concentrations would be reduced over some time frame in response to an IR, which is expected to result in a reduction in ecological and human health risk.

1.3.2.1 Remedial Action Objectives

RAOs for the IR FS (Section 3) are focused on successful completion of the source control remedial action, specifically remediation of contaminated sediment source areas. Once the RAOs have been achieved, outcomes of this action would be anticipated to include reduced human and ecological exposures to contaminants, reduced contaminant transport potential, and accelerated recovery of the remaining sediment and the water column. The RAOs provide a basis for evaluation of the remedial alternatives.

1.3.2.2 Applicable or Relevant and Appropriate Requirements

ARARs are identified for the IR FS and evaluated for applicability to the scope of a source control IR, consistent with EPA guidance (USEPA 1999) (Section 4).

1.3.2.3 Remedial Technologies Screening

A screening of remedial technologies is performed to identify those technologies appropriate for consideration in the implementation of the upper 9-mile IR. Technologies selected as the process options for evaluation in this IR FS and those retained for further consideration during remedial design are specified (Section 5).

1.3.2.4 IR FS Model Projection Runs

The LPRSA Hydrodynamic/Sediment Transport (HST) and Contaminant Fate and Transport (CFT) numerical models are used to support comparative evaluation of the remedial alternatives (Section 6 and Appendix C). The models provide projections of surface water quality and sediment contaminant concentrations during and following the implementation of the IR. The project guidelines established for application of these models in the IR FS are described in Section 6.

1.3.2.5 IR FS Remedial Alternatives

A set of remedial alternatives, including a No Action alternative, is developed for the IR FS (Section 7). The EPA October 10, 2018, Direction Letter (USEPA 2018c) specifies that, at a minimum, alternatives will include alternatives to achieve post-IR 2,3,7,8-TCDD SWACs of 65 nanograms per kilogram (ng/kg),[15] 75 ng/kg, and 85 ng/kg. Pursuant to the Direction Letter, other remedial alternatives that reflect additional post-IR SWACs may also be evaluated, and a fourth active alternative, to achieve a post-IR 2,3,7,8-TCDD SWAC of 125 ng/kg, is included in the IR FS for comparative purposes. The alternatives include the earlier RM 10.9 and Phase 1

[15] Units of ng/kg are equivalent to parts per trillion.

removal actions to represent existing conditions and assume the implementation of the planned lower 8.3-mile remedy.

1.3.2.6 Engineering Assumptions

Engineering assumptions are developed to support evaluation of the remedial alternatives (Section 7.1 and Appendix A). Engineering assumptions include, for example, number and type of dredge(s), dredge production rates, construction season and schedule (including consideration of fish windows), infrastructure setback requirements, residuals generation rates and management methods, dredged material transport, dredged material processing and disposal, beneficial use, and identification and handling of principal threat waste. An evaluation of cap design is presented in the IR FS to support assumptions regarding cap type. The engineering assumptions are representative of potential engineering and construction requirements sufficient to support the IR FS evaluations. The IR FS engineering assumptions do not represent final design criteria. Actual engineering criteria would be established in a remedial design.

1.3.2.7 IR FS Remedial Alternative Footprints

Areas of active remediation (i.e., remedial "footprints") for each of the remedial alternatives are delineated based on the sediment bed mapping developed from sediment data collected during the RI and the sediment stability/erosion evaluation documented in Section 4 and Appendices A and M of the RI report (AQEA 2019). Footprints are defined using RALs for 2,3,7,8-TCDD and total PCBs needed to achieve the RAOs (Section 7.2 and Appendix B).

1.3.2.8 IR FS Evaluation Metrics

Specific evaluation metrics are used in the IR FS to evaluate the extent to which each remedial alternative would be expected to achieve source control and meet the RAOs for an IR. A set of metrics, including model projections, is developed for the evaluation of alternatives (Section 8.1).

1.3.2.9 Detailed and Comparative Analysis of Alternatives

A detailed analysis of the remedial alternatives for the IR FS is performed according to the evaluation criteria specified by EPA guidance (USEPA 1988) and the NCP (40 CFR §300.430(e)(9)(iii)). A comparative evaluation of the remedial alternatives under CERCLA is conducted to assess the relative performance of each alternative with respect to evaluation criteria, to identify trade-offs and uncertainty (Section 8).

1.4 ADAPTIVE MANAGEMENT

Consistent with the goals of the EPA Superfund program, the overall objective of adaptive management for the LPRSA is to ensure the attainment of risk-protective final RGs for the site as expeditiously and cost-effectively as possible. To meet this objective, remedial action for the upper 9 miles of the LPRSA will be adaptively managed under a multistep process. The first step would be the design and implementation of a source control IR for the upper 9 miles. An IR would be followed by a period of recovery assessment monitoring to evaluate the response of the system to the source removal and track the recovery of sediment, the water column, and biota. Based on the results of the recovery assessment monitoring, EPA would issue a final ROD[16] to establish risk-based RGs and specify any additional actions beyond the IR that may be needed to address remaining risks and attain the RGs.

The Adaptive Management Implementation Approach (Appendix D) presents a structured program for identifying key uncertainties that control the understanding and therefore the remediation of the upper 9 miles of the LPRSA. The data that would be collected prior to, during, and following an IR would guide the planned multistep remedial action for the upper 9 miles. The outcome of the process would answer the critical overarching question:

> *What actions are required to promote and attain the overall protection of human health and the environment, initially for the upper 9 miles of the LPRSA and subsequently for the entire LPRSA?*

Activities to support adaptive management of the LPRSA are currently under way, with ongoing data collection to describe current conditions and inform decision-making throughout the program. Adaptive management activities will continue through the IR design phase, when initial PRGs and expected recovery trajectories are established, and through recovery assessment monitoring to assess system response and track progress toward developing and attaining PRGs, issuance of a final ROD, and, ultimately, confirmation of the attainment of final RGs.

The Adaptive Management Implementation Approach includes three adaptive elements: IR Design and Implementation, System Response, and System Recovery. The adaptive elements are key project activities and milestones that are accompanied by decision points that address the overarching goals of identifying information and/or actions that would support attainment of overall protectiveness and, as such, may trigger one or more adaptive responses. Details of each adaptive element are specified in Appendix D.

[16] It is anticipated that the final ROD would address all remaining site risks for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA.

The adaptive management decision framework is intended to support transparent and efficient decision-making for adaptive management. Decisions would be made in accordance with the following general principles:

- The decision frameworks for the adaptive elements are intended to identify the broad parameters and requirements for decision-making for adaptive responses to new information and/or changing site conditions.
- The decisions to be made as part of adaptive management would be informed by the key information inputs that are identified in the plan. The decision frameworks for the adaptive elements identify how the information inputs would be assessed and, where appropriate, integrated into an evaluation using multiple lines of evidence.
- The decision frameworks identify clear decision time frames for each adaptive element, in relation to the overall project time line and CERCLA administrative requirements for the LPRSA.
- While it is impossible to foresee all of the factors that may be relevant to a particular decision, the decision frameworks provide an overall structure for identifying appropriate response actions, considering the overall facts and circumstances that surround each decision point.
- Project stakeholders would participate in evaluating new information and providing input to decision makers on appropriate adaptive responses, when needed. When a critical decision point is reached, it is assumed that stakeholders and decision makers would abide by the guidelines and decision protocols identified in the plan for each adaptive element to the maximum extent reasonably possible.

Implementation of adaptive management to incorporate new information, reduce uncertainty, and support project decision-making would be informed by and closely coordinated with several phases of monitoring activities to be performed before, during, and following the completion of an IR. These monitoring activities and their role in supporting the adaptive management process for the upper 9 miles are described in Appendix D.

1.5 DOCUMENT ORGANIZATION

Subsequent sections of this IR FS present the following:

- Section 2, "Study Area Setting, Remedial Investigation, and Site Risk Summary," describes the environmental setting of the LPRSA, and summarizes the results of the remedial investigation, human health risk assessment (HHRA) and baseline ecological risk assessment (BERA).
- Section 3, "Remedial Action Objectives," presents the RAOs and supporting discussion.

- Section 4, "ARARs," presents ARARs and TBCs for the upper 9 miles of the LPRSA.
- Section 5, "Identification and Screening of Remedial Technologies," describes a broad array of known potential technologies for sediment remediation and disposal and then screens those technologies to identify representative process options based on site-specific factors.
- Section 6, "Modeling to Support the Evaluation of Remedial Alternatives," summarizes the role of models to support the IR FS.
- Section 7, "Development of Remedial Alternatives," describes the remedial alternatives that are assembled for detailed evaluation based on consideration of the RAOs, RALs, target areas, and the results of the technology screening. A No Action alternative, as required under CERCLA, is also described.
- Section 8, "Detailed Evaluation and Comparative Analysis of Remedial Alternatives," evaluates remedial alternatives individually against the seven threshold and balancing criteria defined under CERCLA and in accordance with the specific steps and guidelines described in EPA guidance (USEPA 1988). The comparative analysis builds on the detailed evaluation of individual alternatives by directly comparing their performance against the seven CERCLA threshold and balancing criteria and with the No Action alternative.
- Section 9, "References," presents full citations for the references cited in this report.

Details that support various analyses in the FS are presented in the following appendices:

- Appendix A, "Design Assumptions and Construction Quantities," presents the engineering assumptions used to develop the remedial alternatives and cost estimates.
- Appendix B, "Development of Remedial Alternatives Footprints," presents the approach to sediment bed mapping and delineation of remedial footprints.
- Appendix C, "Interim Remedy Feasibility Study Model Projections," presents the application of the numerical models to support the IR FS
- Appendix D, "Adaptive Management Implementation Approach for the Upper 9 Miles of the Lower Passaic River Study Area," presents the adaptive management process and decision framework for the remediation of the upper 9 miles of the LPRSA.
- Appendix E, "Lessons Learned from Early Actions on the Lower Passaic River," summarizes relevant lessons and outcomes that inform the IR FS and can inform the remedial design.
- Appendix F, "Conceptual Cap Design Evaluation," presents the cap modeling performed to support the IR FS.

- Appendix G, "Cost Estimates," presents the IR FS-level cost estimates for the remedial alternatives.
- Appendix H, "Interim Remedy Completion Evaluation Framework," presents the decision process for confirming completion of an IR.
- Appendix I, "Green and Sustainable Remediation Evaluation," presents the model outputs supporting the evaluation.
- Appendix J, "EPA/NJDEP/CPG IR FS Meeting Minutes" presents the final meeting minutes form the collaboration meetings held to develop the framework and basis for this IR FS.

2 STUDY AREA SETTING, REMEDIAL INVESTIGATION, AND SITE RISK SUMMARY

Background information on the history and physical setting of the LPRSA and a summary of the key findings of the remedial investigation and risk assessments are presented with a focus on the upper 9 miles of the LPRSA. The RI (AQEA 2019), BERA (Windward 2019), and HHRA (AECOM 2017) provide a description of the 17-mile study area, contaminant patterns and fate and transport, and ecological and human health risk assessments.

2.1 SITE DESCRIPTION

The Passaic River originates in the Highlands of New Jersey and flows through the Central Basin wetlands into Newark Bay. The Passaic River Basin is the third largest drainage system in New Jersey, draining over 950 square miles (Spitz et al. 2007). The LPRSA is the tidally influenced portion of the Passaic River that begins at Dundee Dam (RM 17.7, which is RM 17.4 in the RI RM system) and ends at Newark Bay (RM 0; see Figure 1-2). It is part of the Greater Newark Bay Complex, along with Newark Bay, Hackensack River, Arthur Kill, and Kill Van Kull (Figure 1-1). These waterbodies are connected through freshwater flows from the rivers to the ocean and by tidal flows that move water both inland and toward the ocean. The tidal flows also connect the Greater Newark Bay Complex to New York Harbor and Raritan Bay (also referred to as the NY/NJ Harbor Estuary or the Hudson-Raritan Estuary).

2.2 SITE HISTORY

The Passaic River is located within one of the major centers of the American industrial revolution. Early manufacturing was established near Paterson, New Jersey, during the post-colonial era. Beginning with cotton mills, the LPR watershed, concentrated along the river, grew to include manufactured gas plants; petroleum refineries; tanneries; shipbuilding; smelting; pharmaceutical, electronic product, dye, paint, pigment, paper and chemical manufacturing plants; and other industrial activity (MPI 2007). Major population centers such as Paterson and Newark transformed the watershed into a mix of residential, commercial, and industrial uses. Thus, like many other urban systems, the Passaic River has been subjected to a broad range of contaminant loadings from multiple sources (e.g., untreated industrial and municipal wastewater, combined sewer overflows [CSOs]/stormwater outfalls [SWOs], direct runoff, and atmospheric deposition) for a long time.

The LPRSA first became the focus of investigation because of contamination resulting from discharges from the former manufacturing facility located at 80 and 120 Lister Avenue in Newark, New Jersey (herein referred to as the Lister Avenue site). The Lister Avenue site, located at RM 3.4, was the home of various companies for more than 100 years. Kolker

Chemical Works manufactured DDT and other pesticides at the Lister Avenue site in the 1940s. In 1951, the Diamond Alkali Company acquired Kolker Chemical Works. Between 1951 and 1969, the Diamond Alkali Company (subsequently known as the Diamond Shamrock Chemicals Company, now OCC) manufactured chemicals such as pesticides and phenoxy herbicides, including the primary components used to make the military defoliant Agent Orange. 2,3,7,8-TCDD (a by-product of phenoxy herbicide manufacturing), DDT, and other chemicals were discharged from the former manufacturing facility and released into the river. Investigators have since concluded that the Lister Avenue site was the dominant source of 2,3,7,8-TCDD and a significant source of DDT to the river (Bopp et al. 1991, 1998; Chaky 2003; Hansen 2002; Israelsson et al. 2014; Quadrini et al. 2015; Garland 2017).

In 1983, high levels of 2,3,7,8-TCDD were detected in onsite and offsite soils and groundwater at the Lister Avenue facility. Based on these findings, in September 1984, EPA added the Diamond Alkali Superfund Site to the National Priorities List. EPA also identified pesticides, volatile organic compounds, and other hazardous substances in the groundwater at the site. In 1994, OCC (through the property owner Chemical Land Holdings, then known as Tierra Solutions Inc., a subsidiary of Maxus Energy Corporation[17]) investigated a 6-mile stretch of the LPR (RM 1 to RM 7) under EPA oversight. The investigation identified significant sediment contamination, and showed that contaminated sediment had moved upstream and downstream of this 6-mile stretch, leading EPA to expand the investigation in 2002 to include the stretch of the Passaic River to Dundee Dam and Newark Bay as additional OUs.

2.3 ENVIRONMENTAL SETTING

Freshwater and solids loading to the LPR from the watershed are dominated by the inflow from the Upper Passaic River at Dundee Dam, with several tributaries contributing to a lesser degree. The LPRSA also receives brackish water and solids from Newark Bay via tidal exchange and density-driven currents, which, together with the freshwater flow, dictate the movement of sediment within the estuary. A 15.4-mile-long federal navigation channel was created in the late nineteenth century to facilitate industrial activity along the river. The channel between RM 1.9 and RM 8.3 was last maintained in or before 1950. The last maintenance dredging in the lower 1.9 miles of the channel was conducted in 1983. Most of the channel upstream of RM 8.3 was last dredged in the 1970s.[18] Infilling and trapping of sediment-bound contaminants within the navigation channel have occurred to varying degrees since the cessation of maintenance

[17] Tierra and Maxus Energy Corporation went into bankruptcy in 2017.
[18] The stretches of the navigation channel from USACE RM 8.5 to USACE RM 9.6, USACE RM 10 to USACE RM 10.6, USACE RM 11 to USACE RM 12.1, USACE RM 12.4 to USACE RM 12.8, USACE RM 13.9 to USACE RM 14, and USACE RM 14.3 to USACE RM 15 were last maintained before 1950.

dredging. The federal navigation channel upstream of RM 1.7 was deauthorized in June 2018 (Section 3021 of America's Water Infrastructure Act of 2018[19]).

The LPRSA's physical characteristics have been altered by industrialization and urbanization. Most tidal marshes, wetlands, and mudflats were filled in or dredged, gradually transforming the LPR into a highly channelized river. River banks in the upper 9 miles are dominated by hardened shorelines (e.g., sheetpile, riprap, and wood pilings) (MPI 2007), and limited areas of mudflats remain along the length of the LPR. Noncontiguous stretches of mudflat habitat are present along approximately 30 percent of the stretch above RM 8. A waterways conditions assessment was performed on behalf of the CPG to characterize the physical condition of structures and engineered shorelines in the LPR (AECOM 2015a). Much of the engineered shoreline in the upper 9 miles (i.e., riprap or bulkhead) was observed to be in fair condition (exhibiting signs of wear, but generally appearing suitable for intended use) at the time of the survey; some areas of shoreline were observed to be in poor (marginally performing its intended use, but in a state of decay and vulnerable to additional damage by undermining or flooding) or failing condition (no longer capable of supporting loads or resisting erosion in flood events) (Figure 2-1).

Land use changes and physical alterations of the LPR shoreline have increased impervious surfaces and severely degraded the riverbank habitat and its ecological function (Iannuzzi et al. 2002). Adjacent land use in the upper 9 miles is approximately 35 percent residential and recreational and 30 percent industrial and commercial (primarily along the east bank), and the west bank of the LPR is abutted by Route 21 over much of the upper 9 miles.

Overall, the sediment characteristics of the LPR are typical of a large estuary, with along-river trends that reflect sediment transport patterns influenced by the expanding cross section, tides, river inflow, and geomorphologic changes. The coarsest sediment occurs in the upper reaches, with finer sediment becoming more common as the river widens and deepens, particularly downstream of RM 8.3 (see RI report Figure ES-3 [AQEA 2019], showing sediment type as defined by side scan sonar). Along bends, the lower water velocities along the inner portion and the lateral circulation moving bottom water toward the inner portion result in the accumulation of finer sediment. Conversely, the higher water velocities along the outer portion prevent the accumulation of finer sediment and result in coarser sediment being present. Moving from the inner bend across the channel toward the outer bend, there is typically a gradual transition from finer to coarser sediment. The fine sediment along the inner bend tends to form point bars, including the RM 10.9 point bar, which was partially dredged and capped in 2013 and 2014 (excluding the utility corridor) to address elevated 2,3,7,8-TCDD, PCB, PAH, and mercury levels. Sediment tends to be coarse or absent (i.e., the bottom is rock and gravel) near structures such as bridge abutments and at tributary confluences due to associated turbulence,

[19] https://www.congress.gov/bill/115th-congress/senate-bill/3021

particularly under higher flows, that prevent long-term accumulation of fine sediment or, in particularly high-energy areas, any sediment.
Net deposition since the period of highest contamination in the 1950s and 1960s has occurred in much of the lower 8 miles of the river and in portions of the river between RM 8 and RM 15. The evidence for this includes buried cesium-137 peaks and buried peak contaminant concentrations, as documented in the RI report (AQEA 2019). In some locations such as the mudflats at and upstream of RM 7, the deposition that formed these mudflats likely slowed or ceased as a quasi-equilibrium was reached, leaving 1960s sediment at or near the surface of the mudflats, particularly in their upper portions. Other areas within these mudflats appear to have been subject to more recent deposition, as evidenced mainly by core profiles and longitudinal gradients in surface sediment contaminant concentrations (see Section 2.4). Even where net deposition has occurred on the scale of decades, dynamic erosion and deposition likely occurred and continues to occur on short timescales. Evidence for cyclical erosion and deposition comes from changes in bathymetry documented in the series of multibeam bathymetry surveys conducted between 2007 and 2012, a period characterized by several high flow events. More recently, there is evidence of ongoing deposition from the long-term monitoring of the remediated portion of the RM 10.9 point bar, which indicates several inches or more of sediment accumulation on top of the engineered cap since its placement in 2013 to 2014 (AECOM 2018).

Tidal resuspension is a major driver of water column concentrations of suspended sediment and contaminants, and during low-flow conditions, it reflects mainly the mobilization of a thin layer of unconsolidated sediment, termed a fluff layer. Erosion of the underlying consolidated sediment bed occurs mainly during significant storm events, during which eroded sediment may redeposit elsewhere or migrate out of the river. Erosion appears to be most significant on edges of the channel, downstream of bridge abutments, in areas of constricted cross sections, and in the more sinuous portions of the lower 5 miles. Detailed evaluations of erosion and deposition patterns for the upper 9 miles of the LPR are presented, along with evaluations of sediment type and contaminant concentration patterns, in Sections 4.2.1 through 4.2.7 of the RI Report (AQEA 2019).

Chemical contamination has impacted LPR biota and limited the ecological value and habitat suitability of the LPR. The historical urbanization and industrialization of the system has also resulted in the LPR exhibiting characteristics that are symptomatic of the "urban stream syndrome" (Walsh et al. 2005), including a higher frequency of flash floods, elevated nutrient levels, altered stream morphology, increased amounts of tolerant species, decreased amounts of sensitive species, and an overall decreased diversity, compared to streams not impacted by urbanization. Physical modifications to the river associated with urbanization in conjunction with releases of hazardous substances and discharges of pollutants have resulted in reduced ecological function.

2.4 NATURE AND EXTENT OF CONTAMINATION IN THE UPPER 9 MILES

The RI Report (AQEA 2019) examines the nature and extent of contamination for the COCs 2,3,7,8-TCDD, total PCBs, total DDT and its metabolites [DDx],[20] mercury, high-molecular-weight (HMW) PAHs, and low-molecular-weight (LMW) PAHs. It evaluates spatial trends and relationships between concentrations and sediment type. The overall conclusion is that for most of the COCs in the LPR, concentrations tend to be highest in fine sediment. This association reflects the higher amount of organic matter in fine sediment and the importance of organic carbon in sorbing many of the contaminants in the river. The decreasing occurrence of fine sediment moving upstream contributes to the large-scale longitudinal trend in contaminant concentrations. That trend also reflects the estuarine transport patterns that facilitate upstream as well as downstream movement of water, solids, and associated contaminants.

Examining the data at a finer spatial scale (see RI Section 4) reveals patterns in 2,3,7,8-TCDD, total PCBs, total DDx, and mercury concentrations that are largely driven by variations in sediment type and depositional/erosional history. Concentrations of these contaminants generally correlate (to varying degrees) with sediment type, as noted above, although the range of concentrations is large, particularly within fine sediment. That range seems to reflect geomorphic evolution and susceptibility to episodic erosion and cyclic erosion/deposition. The higher surface (0- to 6-inch [in.]) concentrations tend to be in fine sediment located in areas that have not been net depositional in the last few decades. Surface concentrations in fine sediment in depositional areas are reflective of contaminant concentrations in particulate matter in the water column. PAH concentrations do not tend to vary with sediment type; comparable levels of HMW PAHs and LMW PAHs are found in fine and coarse sediment.

2.4.1 Surface Sediment Contaminant Concentration Patterns

Concentration patterns in surface sediment are illustrated here for 2,3,7,8-TCDD and total PCBs (Figure 2-2a,b).[21] A thorough discussion of sediment contamination patterns for all contaminants can be found in Section 4 of the RI (AQEA 2019).

From RM 8 to RM 14,[22] concentrations are characterized by large variability, with 2,3,7,8-TCDD ranging from less than 1 ng/kg to a maximum of 51,100 ng/kg and total PCBs ranging from less than 0.01 milligrams per kilogram (mg/kg)[23] to a maximum of 33.9 mg/kg (Figure 2-2a,b and

[20] Total DDx refers to the sum of the 2,4′- and 4,4′- isomers of dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethene (DDE), and dichlorodiphenyldichloroethane (DDD).
[21] The analyses, tables, and figures presented in Section 2 reflect pre-RM 10.9 removal conditions while the analyses, tables, and figures presented in Sections 7 and 8 and Appendix C incorporate post-RM 10.9 removal conditions (as discussed in the description of model initial conditions in Section 3.1 of Appendix C).
[22] These RMs use the RI system for consistency with that report. Elsewhere in the IR FS, the RMs are based on the USACE RM system. An approximate conversion to USACE RMs is to add 0.3 to the RI RMs; the exact conversion varies from 0.2 to 0.3 along the river.
[23] Units of mg/kg are equivalent to parts per million.

Table 2-1). As evident in the color scale in Figures 2-2a and 2-2b, higher concentrations are predominantly in sediment with greater than 60 percent fine sediment. Higher concentrations that are also observed in coarser sediment (e.g., in the 20 to 40 percent fine sediment range) are presumably associated with the fine fraction of this sediment. Many of the high concentrations are found on point bars formed along the inner bends of the LPR at RM 8.5, RM 10.1, and RM 10.9. Sediment 2,3,7,8-TCDD and total PCB concentration patterns in these point bars reflect their evolution. Surface concentrations are generally higher in the central area of the point bar and lower in nearshore and offshore portions. The high-density sediment data collected on the RM 10.9[24] point bar (which was subject to dredging and capping in 2013–2014) are instructive in understanding the physical and chemical characteristics of point bars in the LPR. 2,3,7,8-TCDD concentrations greater than 1,000 ng/kg occur where 1960s-era sediment is at the surface (Figure 2-3, left panel).[25] Sharp transitions to lower concentrations are typically observed moving toward the edge of the channel. The channel in the vicinity of this point bar is characterized by lower surface sediment concentrations generally in the range of 10 to 100 ng/kg, consistent with the coarse nature of the sediment. Surface concentrations are typically less than 500 ng/kg in the southerly portion of the RM 10.9 point bar, consistent with ongoing geomorphic evolution characteristic of the downstream portion of a point bar. Similar patterns are observed 0.5 to 1.5 feet (ft) below the surface (Figure 2-3, right panel). As noted in Sections 4.2.6 and 4.2.7 of the RI, concentrations in the RM 8.5 and the RM 10.1 point bars are also higher in the upstream portion than in the downstream portion.

Upstream of RM 12, 2,3,7,8-TCDD concentrations generally decline, as do total PCB concentrations but to a lesser extent. Concentrations of 2,3,7,8-TCDD greater than 500 ng/kg and concentrations of total PCBs greater than 1 mg/kg are confined mainly to fine sediment regions influenced by tidally driven net upstream transport from the lower river, which can extend to beyond RM 14 under very low flow conditions. The highest concentrations upstream of RM 14 are found in the silt and sand deposit at the first (upstream) oxbow at RM 14.5, reflective of the finer sediment there. Outside the fine sediment deposits, concentrations above RM 12 are mostly less than 100 ng/kg for 2,3,7,8-TCDD and 1 mg/kg for total PCBs. Surface sediment concentrations upstream of RM 14.6 are less than 1 ng/kg for 2,3,7,8-TCDD and 0.5 mg/kg for total PCBs, reflecting the coarse sediment there and the lower concentrations originating from upstream of Dundee Dam.

The concentration patterns for total DDx and mercury tend to mirror those of 2,3,7,8-TCDD in the region downstream of RM 14. Patterns of HMW PAHs and LMW PAHs vary from those of the other contaminants, with no clear difference between concentrations in fine and coarse sediment. Upstream of RM 14, none of these contaminants shows the dramatically lower

[24] The data discussed here were collected prior to the time-critical removal action in RM 10.9.
[25] Figure 2-3 shows data collected in the RM 10.9 point bar prior to the time-critical removal action in 2013 to 2014.

concentrations evident for 2,3,7,8-TCDD because of the influence of sources from above Dundee Dam on sediment concentrations.

2.4.2 Biota Contaminant Concentration Patterns

While there is variability in contaminant levels in biota tissue spatially, as well as within and between species, some general trends were observed based on the benthic invertebrate and fish tissue data collected from the LPR. Organic contaminants, including 2,3,7,8-TCDD, total PCBs, and total DDx, are generally highest in large benthic omnivorous fish, with the highest concentrations found in carp. Concentrations of 2,3,7,8-TCDD, total PCBs, and total DDx in the upper 9 miles tend to be highest in fish tissue samples from below RM 10.1, with the exception of carp (where the highest concentrations tend to be in fish tissue samples from below RM 12.5). Lower concentrations were observed in samples from above Dundee Dam for these COCs. HMW PAHs and LMW PAHs are also generally higher in the benthic omnivores, but differ from the contaminants discussed above in that PAH concentration ranges in fish from the LPR mostly overlap with concentration ranges in fish from above Dundee Dam. Mercury concentrations in LPR fish tissue generally increase with increasing trophic level and are similar or even lower than those measured in fish collected above Dundee Dam.

2.4.3 Contaminant Transport and Natural Recovery

The surface sediment patterns discussed above reflect a complex exchange of contaminants between the sediment bed and the water column, which occurs primarily through erosion and deposition.

Erosion during low flows is generally limited to a millimeter-scale surficial fluff layer of unconsolidated sediment and extends only into the underlying bedded sediment during higher flows. Resuspended contaminants are transported along the river by riverine and estuarine processes, mixing with contaminants originating from other portions of the LPR and from external sources (e.g., Passaic River above Dundee Dam and tributaries) while redistributing in a COC-specific manner to the dissolved phase and other suspended solids. The sorbed fraction may settle to the sediment bed, thus creating a mechanism for areas of high concentration to influence areas of lower concentration (and vice versa). Water column measurements from the small volume Chemical Water Column Monitoring program indicate that 2,3,7,8-TCDD concentrations are low just upstream of Dundee Dam, highest within the LPR in the vicinity of the estuarine turbidity maximum (i.e., the region of an estuary with maximum turbidity that is associated with solids trapping), and decrease through the lower miles of the LPR into Newark Bay in a manner analogous to the large-scale trends in surface sediment. Modeling indicates that the LPR is a net exporter of 2,3,7,8-TCDD to Newark Bay, with the export being strongest during high-flow events when some areas of the river bottom experience scour. Section 6 of the RI report (AQEA 2019) presents a discussion of the mass inventory patterns that have resulted from the time integration of these transport processes.

Natural recovery of surface sediment concentrations (i.e., a decline) can occur through deposition of cleaner solids from the water column that mix with surface sediment. In areas undergoing cyclical deposition and erosion, such mixing causes dilution of the surface sediment. In areas undergoing net deposition, the surface sediment is also buried by the cleaner solids. Other processes that can potentially contribute to recovery of surface sediment include erosion of the surface sediment, diffusion of contaminants to the water column, and biological or chemical degradation.

Sedimentation has reduced average contaminant concentrations in LPR surface sediment since the 1950s and 1960s, when the most substantial contaminant releases occurred. Areas with high sedimentation rates have exhibited the greatest recovery since the 1960s as evidenced by lower concentrations in surface sediment than at-depth (Figure 2-4).

Changes in surface sediment 2,3,7,8-TCDD concentrations from the mid-1990s (i.e., 1995 to 1999 data) to the late 2000s (i.e., 2005 to before Hurricane Irene in 2011) can be best examined in the reach between RM 1 and RM 7. These changes (Figure 2-5a shown in orange and green) suggest that recovery occurred in areas that experienced 6 in. or more of net deposition and perhaps in shallow areas outside the extent of the bathymetry surveys (shown as "No Bathymetry Data" on Figure 2-5a). In areas that experienced net deposition, mean 2,3,7,8-TCDD concentrations declined from about 680 to about 260 ng/kg and the median dropped from about 310 to about 220 ng/kg. In areas without bathymetry data, smaller declines are suggested; the mean declined from about 500 to 370 ng/kg and the median declined from about 320 to 270 ng/kg.[26] Erosional areas and areas where bathymetry change could not be reliably quantified (i.e., < 6 in.) had small declines in mean concentration, but no decline (erosional) or a small increase (less than quantifiable change) in median concentration. Total PCBs exhibited similar trends though the relative changes were smaller, likely reflecting the influence of background sources (Figure 2-5b). In depositional areas, the mean concentration of total PCBs declined from about 1.5 mg/kg to about 1.0 mg/kg, with little change in median concentration. Similar recovery patterns are noted for total 4,4'-DDx[27] and mercury. HMW PAHs and LMW PAHs show no evidence of recovery, likely due to ongoing sources (see Section 10 of the RI report, AQEA 2019).

It appears that erosion during the 1-in-90-year high flow event that resulted from Hurricane Irene in August 2011 caused an uptick in concentrations that impacted recovery. The uptick can be seen on Figures 2-5a and 2-5b (purple bars); the bathymetry categories shown here are based

[26]The areas outside the coverage of the 1995 and 2010 bathymetry surveys were mostly in shallower areas near the shoreline (gray areas in Figure 10-5 of the RI report). Although long-term net sedimentation cannot be judged, recovery is plausible via net deposition or cyclic erosion/deposition.

[27] Historical data from 1995 to 1999 are available for total 4,4'-DDx but not total DDx. To allow the use of the historical data, total 4,4'-DDx is used in assessing recovery rather than total DDx. For more information, see the comparison of total DDx and total 4,4'-DDx for the post-2005 data in Figure 8 in Appendix I of the RI report. This figure indicates that total 4,4'-DDx is well correlated to total DDx and constitutes most of the total DDx.

on changes from 1995 to 2010 for consistency with the pre-Hurricane Irene comparisons (i.e., the categories do not reflect bathymetric changes during Hurricane Irene). Average surface sediment concentrations in the post-Hurricane Irene data set exceed those of pre-Hurricane Irene for most of the COCs examined. An increase in the mean surface sediment concentrations is consistent with model predictions, which also indicate that mean concentrations declined during the post-Hurricane Irene period (RI Section 7, AQEA 2019).[28]

Recovery of biota tissue 2,3,7,8-TCDD, total PCBs, total 4,4'-DDx, mercury, LMW PAHs, and HMW PAHs concentrations was assessed by comparing concentrations from historical (1995 to 2004) and more recent (2009 to 2010) data sets (RI Section 10, AQEA 2019). Generally, total PCB concentrations were found to have declined, but patterns for the other chemicals are not clear. Variability in concentration trends may be due to differences between the historical tissue data collected in the 1990s and early 2000s within the 6-mile study area versus the 2009/2010 17-mile RI/FS biota sampling, including the number of samples, timing of the sampling, species sampled, metabolization of PAHs, and other factors. The large degree of variability in tissue data collected to date from the LPR inhibits definitive conclusions regarding trends with these data sets. LBG (2014a) reached similar conclusions in the FFS regarding the uncertainty associated with data comparability between historical and more recent (2009/2010) tissue concentration data sets from the lower 8.3 miles of the LPR (RI Report p. 207, AQEA 2019). The ongoing Current Conditions biota tissue collection program for the upper 9 miles is intended to provide a baseline for tissue concentrations, and together with post-IR tissue sampling, provide a line of evidence for post-IR recovery monitoring.

Section 10 of the RI report (AQEA 2019) presents additional details on the analysis of natural recovery in the LPR.

2.4.4 Impact of Ongoing External Sources

Contaminant sources outside the LPR influence recovery and can limit the benefits of active remediation by recontaminating remediated areas. Such sources exist for all the contaminants (total PCBs, PAHs, mercury, and total DDx) except 2,3,7,8-TCDD. As observed in Figure 2-6, mean surface sediment 2,3,7,8-TCDD concentrations in the lower 12 miles of the LPR are on average approximately an order of magnitude higher than upper Newark Bay and two orders of magnitude higher than above Dundee Dam.[29] Mean surface sediment concentrations of total PCBs, PAHs, mercury, and DDx in the lower 12 miles of the LPR are however comparable to those above Dundee Dam and/or in upper Newark Bay.[30] This suggests that remediation of the

[28] See Section 2.6 for further discussion of erosion during high flow events in the context of recovery and the subsurface concentrations considered in the IR FS.
[29] Mean organic carbon (OC)-normalized surface sediment 2,3,7,8-TCDD concentrations in the lower 12 miles of the LPR, upstream of Dundee Dam, and in Upper Newark Bay are 31,825, 187, and 3,415 ng/kg-OC, respectively.
[30] Mean surface OC-normalized concentrations of total PCBs in the lower 12 miles of the LPR, upstream of Dundee Dam, and in Upper Newark Bay are 52, 24, and 22 mg/kg-OC, respectively. Corresponding values for the other

LPR sediment in the absence of source control has the potential to significantly reduce the levels of 2,3,7,8-TCDD but long-term reductions of the other contaminants (i.e., total PCBs, PAHs, mercury, and total DDx) may be limited due to recontamination from the upper Passaic River and Newark Bay. Source control efforts in the Passaic River upstream of Dundee Dam and Newark Bay that address the other contaminants or reductions occurring via natural recovery would reduce the effects of recontamination.

Point sources (e.g., CSOs, SWOs, industrial and municipal discharges) also have the potential to be ongoing sources. Targeted sampling of LPRSA CSO/SWO point sources, performed as part of the Contaminant Assessment and Reduction Project model sampling effort in 2000 to 2004 (Great Lakes Environmental Center 2008) and during the 2007 to 2008 EPA field effort, indicate that CSOs and SWOs were not a significant source for key contaminants in the Passaic River in the time period that these studies were performed (LBG 2014b). Based on these studies, it was estimated that CSOs and SWOs contributed less than 3 percent of the solids entering the LPR (LBG 2014b).

Non-point sources, such as groundwater flux and direct atmospheric deposition, are not believed to be major contaminant sources to the LPR. EPA concluded in 2008 that chemical inputs from groundwater discharges are negligible throughout the LPR (correspondence between EPA and CSTAG [USEPA 2008b]), and The Louis Berger Group concluded that the estimated groundwater discharge to the LPR is less than 2 percent of the long-term average river flow over Dundee Dam (LBG 2014b). Atmospheric contributions of 2,3,7,8-TCDD to the LPRSA are expected to be small and diffuse relative to the contributions from dredging, erosion, and resuspension flux from historically contaminated sediment to the water column (Bopp et al. 1991; Chaky 2003; USEPA 2008b).

2.5 SUMMARY OF BASELINE HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENTS

The baseline HHRA (AECOM 2017) and the BERA (Windward 2019) were performed for the LPRSA as part of the RI/FS. These risk assessments were conducted in accordance with EPA risk assessment guidance (USEPA 1989a,b, 1991b,c, 2001, 2002, 2004a,b, 2005, 2009, 2014) and using methods and procedures that reflect EPA Region 2 and CPG agreements and agency directives. The risk assessments are summarized below and presented in full in Appendix D to the RI report (AQEA 2019).

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contaminants are HMW PAH: 952, 1,882, and 595 mg/kg-OC; LMW PAH: 238, 805, and 78 mg/kg-OC; mercury: 60, 39, and 127 mg/kg-OC; and DDx: 4, 2, and 1.4 mg/kg-OC.

2.5.1 Baseline Human Health Risk Assessment

The baseline HHRA was performed to identify unacceptable risks to human health in the LPRSA. The baseline HHRA evaluated a range of potential receptors (child and adult anglers, swimmers, waders, boaters, and workers) and exposure pathways (ingestion of fish and crab, direct contact with sediment and surface water). Consistent with EPA guidance, the baseline HHRA evaluated both reasonable maximum exposure (RME) and central tendency exposure (CTE) scenarios to provide a range of potential exposures and risks. The RME is intended to represent a conservative upper bound estimate of exposure while the CTE uses average exposure parameters to represent the average exposure to an individual. Both RME and CTE scenarios were included in the baseline HHRA to provide risk managers with an estimate of the range of risks; however, risk management decisions are based on the RME (USEPA 1989b). The exposure assumptions were intended to represent potential exposures under both current and future site uses. The ingestion rates for both fish and crab were provided by EPA Region 2 from its evaluation of available data for the NY/NJ Harbor area. Exposures to accessible surface sediment, surface water, fish fillet tissue, and crab edible tissue were evaluated on a site-wide basis. A refined spatial scale was also applied to sediment, evaluating 3-mile river segments with similar characteristics as separate exposure areas.

The predominant source of human health risk is consumption of fish and crab. Direct exposures to surface water and sediment do not pose risks in excess of the NCP cancer risk range of 10^{-6} to 10^{-4} or noncancer hazard index of 1, with the possible exception of accessible surface sediment in the RM 6 to RM 9 reach (particularly the East Bank). The primary human health risk drivers for the fish and crab consumption scenario are 2,3,7,8-TCDD and total PCBs. The preliminary COCs and risks are summarized in Table 2-2. Upstream and regional levels of several preliminary COCs, including pesticides and mercury, are elevated and may contribute similar risks to the LPRSA. Risks from total PCBs above Dundee Dam were about one-third the risks for total PCBs in the LPRSA. The composition of the fish diet has a bearing on the magnitude of risk as some species exhibit greater tissue burdens of contaminants than others; a diet that includes carp poses potential risks as much as four-fold higher than a diet without carp. A crab diet that includes the hepatopancreas, in addition to muscle tissue, poses potential risks that are five- to six-fold higher than a diet of muscle tissue only. However, consumption of LPRSA fish or crabs poses human health risks in excess of NCP risk levels, even for those diets that exclude carp or focus on crab muscle alone.

2.5.2 Baseline Ecological Risk Assessment

The objective of the BERA was to identify unacceptable risks posed by site-related chemicals to ecological receptors in the LPRSA. Ecological receptors evaluated included benthic invertebrates, macroinvertebrates, molluscs, fish, birds, mammals, zooplankton, amphibians/ reptiles, and aquatic plants. The potential for unacceptable risk was assessed using empirical and modeled data collected from a variety of chemical and biological sampling events and

surveys conducted as part of the LPRSA RI. A step-by-step process included an initial screening level ecological risk assessment, which identified media-specific chemicals of potential ecological concern (COPECs). Site-specific exposure data and a range of effect-level thresholds were used to derive risk estimates (expressed as hazard quotients) to identify the potential for unacceptable ecological risk under baseline conditions using multiple lines of evidence. COPECs with hazard quotients greater than or equal to 1.0 based on effect-level toxicity reference values were identified as preliminary ecological COCs (Table 2-3).

Ecological risk drivers were identified based on a comparison to background concentrations and the results of the uncertainty of the assessment for each preliminary ecological COC and line of evidence evaluated in the BERA. Data used to define background conditions for the BERA were based on data collected by CPG (above Dundee Dam since 2007) per the EPA-approved benthic Quality Assurance Project Plan (Windward 2012) and regional data collected by other parties from Jamaica Bay (New York) and the Mullica River and Great Bay (New Jersey) as directed by EPA (USEPA 2013b).

For sediment background, data sets were developed for both freshwater and estuarine sediment chemistry:

- Freshwater background concentrations (i.e., urban habitat) were derived from sediment samples collected by CPG from above Dundee Dam in 2008 and 2012.
- Two data sets were developed for estuarine background using regional data collected by non-CPG parties. Sediment samples collected from Jamaica Bay from 1993 to 2005 were used to derive background estuarine sediment concentrations representative of a similarly urban environment. Sediment samples collected from the Mullica River and Great Bay from 1999 to 2006 were used to derive estuarine background sediment concentrations (rural habitat). Only sediment chemistry data with co-located toxicity data were used.

Tissue background data sets were developed using tissue samples collected by CPG from above Dundee Dam in 2012 and tissue samples collected by non-CPG parties from Jamaica Bay and Lower Harbor in 1999 and from the Mullica River and Great Bay in 1999 and 2000.

The surface water background data set was developed using surface water chemistry samples collected from 2011 to 2013 from one location above Dundee Dam during the five routine monitoring events, single low-flow event, and two high-flow events.

In addition to ecological risk drivers, a weight-of-evidence approach was evaluated to draw conclusions about the benthic invertebrate community using a sediment quality triad approach. For the evaluation of reference information, toxicity test data included 24 surface (0 to 15 cm) sediment samples with co-located sediment chemistry and benthic invertebrate community data collected from above Dundee Dam in 2012.

Unacceptable risk to ecological species based on exceedances of a range of effect-level thresholds for various ecological receptor groups and lines of evidence is primarily driven by exposure to polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans, total PCBs, and total DDx; these were the ecological risk drivers identified in the BERA. An evaluation limited to just the upper 9 miles of the LPR resulted in the same list of ecological risk drivers as in the BERA for the LPRSA. Some lines of evidence are stronger than others and should be weighted more heavily when used for management decisions. While there are statistically significant relationships between observed benthic community impairment and sediment chemistry/habitat conditions, the statistical relationships for individual contaminants are not strong.

2.6 CONCEPTUAL MODEL OF NATURAL RECOVERY IN SURFACE SEDIMENT IN THE UPPER 9 MILES

Natural recovery of surface sediment COC concentrations occurs principally as a result of lower concentration depositing particles burying surface sediment or diluting surface sediment via cyclical erosion and deposition. The rate of recovery is likely controlled by net erosion of higher concentration sediment and cyclical erosion and deposition that bring higher subsurface concentrations into the surface layer. These processes inhibit the downward trends in water column concentrations that would be needed to reduce concentrations on depositing particles and accelerate recovery. Surface sediment responsible for inhibiting recovery is that with COC concentrations higher than the ambient water column condition. This idea is grounded in the basic principle that net COC flux is directed from higher to lower concentration. Sediment is a net source to the water column where sediment concentrations are greater than those found on particles depositing from the water column. That source can be diffusive flux driven by the concentration gradient, intratidal resuspension of unconsolidated material on the sediment surface (fluff layer), or the episodic erosion of bedded sediment that might occur during high flow events. A conclusion from this principle is that remediating sediment with COC concentrations higher than on the particles depositing from the water column will significantly reduce concentrations on those particles and accelerate concentration reductions in the remaining sediment. This higher concentration sediment is considered source material in this IR FS.

The COC concentrations on particles depositing on the sediment surface were measured by EPA in a 2007 to 2008 study and found to be in the range of 200 to 500 ng/kg for 2,3,7,8-TCDD and about 1 mg/kg for total PCBs (LBG 2014b). Analyses in the RI report show that late-2000s surface sediment in depositional areas has an average 2,3,7,8-TCDD concentration of 260 ng/kg (AQEA 2019, Section 10). Concentrations on sediment that has deposited on the cap in the RM 10.9 removal action area have an average of 211 ng/kg for 2,3,7,8-TCDD and 0.8 mg/kg for total PCBs (AECOM 2018). These data suggest reasonable concentration thresholds for sediment

impeding natural recovery are 2,3,7,8-TCDD concentrations higher than 200 ng/kg and perhaps as high as 400 ng/kg and total PCBs higher than approximately 1 mg/kg.

Sediment with 2,3,7,8-TCDD concentrations in the range of 200 to 300 ng/kg mostly show recovery potential that is indicated by sediment accumulations with concentrations like those of the depositing particles. Twelve cores above RM 8 with surface sediment 2,3,7,8-TCDD concentrations in the range of 200 to 300 ng/kg exist within the areas for which bathymetric changes between 2007 and 2012 can be assessed using multibeam bathymetry measurements (CPG 2018a). Eight of those cores have profiles in which one or more subsurface layers (i.e., more than 6 in. below the sediment surface) are in the concentration range of depositing particles, indicating the likelihood of ongoing net deposition.[31] These locations mostly experienced little measurable bathymetric change between 2007 and 2012, suggesting modest rates of net deposition. Two of these cores located on the side walls of the navigational channel[32] did experience erosion attributable to Hurricane Irene, but that did not expose higher concentration sediment. Two others (one in the navigational channel and one on the side wall[33]) may have been similarly affected by Hurricane Irene, though no 2011 pre-Hurricane Irene bathymetry data exist to support such an evaluation. Of the remaining four cores, one in the navigational channel has essentially no contamination below the surface layer,[34] suggesting a location of temporary deposition, and the other three (two in the navigational channel and one on the side wall) show bathymetric changes suggesting the surface layer represents temporary deposition and that erosion would have exposed higher subsurface concentrations at an earlier time or sometime after the core was collected.[35] Regardless of erosion characteristics, locations with elevated surface concentrations (i.e., in excess of a surface sediment RAL) would be considered sources, consistent with the first RAO. Locations showing evidence of ongoing erosion and elevated subsurface concentrations (i.e., in excess of a subsurface sediment RAL) would be considered sources, in accordance with the second RAO. The RAOs are presented in Section 3.

In the nearshore shallow region lacking multibeam bathymetry data, there are seven cores with surface sediment 2,3,7,8-TCDD concentrations in the range of 200 to 300 ng/kg. Five of these cores have profiles indicating a potential for contemporary deposition; two have subsurface concentrations in the range of depositing particles and the remaining three have subsurface concentrations just above that range. The last two cores have relatively high concentrations below the surface segment indicating a lack of significant contemporary deposition. Regardless of deposition characteristics, and consistent with the paragraph above, locations with elevated surface concentrations would be considered sources, consistent with the first RAO. Locations

[31] CLRC-058 (2008), 13B-0519 (2013), CLRC-056 (2008), 11B-0308 (2011), 11B-0302 (2011), G0000154 (2008), 11B-0305 (2011), 11B-0301 (2011)
[32] 11B-0305 (2011), 11B-0301 (2011)
[33] CLRC-058 (2008), 13B-0519 (2013)
[34] CLRC-064 (2008)
[35] 13B-0516 (2013), CLRC-073 (2008), 12A-0474 (2012)

exhibiting a lack of contemporary deposition and with elevated subsurface concentrations would be considered sources if they are vulnerable to erosion.

Although sediment recovery is suggested by the majority of core profiles reviewed, sediment impeding natural recovery is found at various locations downstream of RM 15. Targeting this sediment in the reach between RM 8.3 and RM 15 would reduce the 2,3,7,8-TCDD SWAC from above 900 ng/kg to 85 ng/kg or lower and the total PCB SWAC from about 1.4 mg/kg to below the upstream background concentration of 0.46 mg/kg. Appendix B presents a detailed discussion of mapping and SWAC calculations.

Erosion that inhibits recovery by exposing and potentially mobilizing higher concentration subsurface sediment rarely extends beyond the top 1.5 ft of sediment. In the area of the river above RM 8.3 examined for bathymetric changes over the period from 2007 to 2012 (including the impact of Hurricane Irene), only 4 percent was categorized as having experienced erosion greater than 1.5 ft (using the bathymetric differencing categories developed in RI Report Section 4; AQEA 2019). The high 2,3,7,8-TCDD concentrations associated with sediment buried by more than 1.5 ft are consequently expected to have a low likelihood of exposure, which is in part supported by the fact that they are still buried in the subsurface despite being subjected to a number of extreme high-flow events in the recent past, including a 90-year flow that resulted from Hurricane Irene in 2011. Although locations where the buried concentrations are associated with recently deposited sediment may be more vulnerable to erosion than older sediment, the buried concentrations in this case likely reflect recent water column particulate concentrations depositing onto the sediment bed and not the higher concentrations associated with older sediment. While it is unknown whether the anticipated increase in the frequency of intense storms (due to climate change) would change the likelihood of exposure of deeply buried contaminants, the sediment armoring associated with large events such as Hurricane Irene act to limit subsequent scour into legacy contaminants.

Reflecting the low likelihood of deep erosion, addressing vulnerability to erosion through the IR is focused on concentrations in sediment at depths of 0.5 to 1.5 ft.

3 REMEDIAL ACTION OBJECTIVES

RAOs for a potential source control IR for the upper 9 miles of the LPRSA were developed in conjunction with EPA, NJDEP, and the CPG. RAOs for the source control IR (USEPA 2018d) are presented and discussed below.

3.1.1 RAO 1—Addressing Surficial Sediment Source Areas

Control the sediment sources of 2,3,7,8-TCDD and total PCBs by remediating surface sediment source areas containing elevated concentrations, thereby reducing the SWACs[36] of 2,3,7,8-TCDD and total PCBs from RM 8.3 to RM 15.[37] Achieve a post-IR 2,3,7,8-TCDD SWAC[38] from RM 8.3 to RM 15 of not more than 85 ng/kg, approximately an order of magnitude higher than the OU2 (i.e., the lower 8.3 miles of the LPRSA) 2,3,7,8-TCDD sediment RG of 8.3 ng/kg,[39] and achieve a post-IR total PCB SWAC[38] from RM 8.3 to RM 15 that is at or below the established total PCB background concentration of 0.46 mg/kg.[39]

3.1.2 RAO 2—Addressing Subsurface Sediment Source Areas

Control subsurface sediment (sediment greater than 6 in. below the sediment bed) from becoming a source of 2,3,7,8-TCDD and total PCBs by remediating sediment between RM 8.3 and RM 15 that has a demonstrated potential for erosion to expose subsurface concentrations above the defined subsurface RALs established for 2,3,7,8-TCDD and total PCBs.

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[36] The SWACs apply to the reach of the LPRSA from RM 8.3 to RM 15 and are calculated based on sediment data representing the surface interval 0 to 6 in. below the surface of the sediment bed. For the IR FS, SWACs are calculated using RI data and the conditional simulation approach presented in the final RI Report for the LPRSA (AQEA 2019, Appendix J). SWACs would be recalculated post-IR selection, based on pre-design sediment sampling data collected at high spatial density, and the recalculated SWACs would be used in the remedial design to define the IR footprint. Post-IR SWACs would be calculated based on surface sediment sampling data for 2,3,7,8-TCDD and total PCBs collected following construction of the IR, including dredging and placement of capping or backfill material.

[37] Existing data suggest the source areas to be targeted by the IR are located between RM 8.3 and RM 15. However, if sediment data collected between RM 15 and Dundee Dam that support IR design identify surface concentrations in excess of a surface RAL (determined during the IR design for RM 8.3 to RM 15) in the reach of RM 15 to Dundee Dam, these areas will be evaluated during IR design to determine whether they constitute a source that is inhibiting the recovery of the LPR. If that determination is made and if it is feasible to address these areas in conjunction with the remediation to achieve the IR RAOs, then these areas will be addressed as part of the IR construction.

[38] In evaluating the post-IR SWACs, the uncertainty in the SWAC calculations will be assessed. The post-IR sampling will be designed and performed to identify an acceptable envelope of uncertainty in the SWAC calculations to support a regulatory determination regarding whether RAO 1 has been achieved. The evaluation methodology is presented in Appendix H.

[39] The 2,3,7,8-TCDD remediation goal (0.0083 µg/kg [8.3 parts per trillion, ppt]) and total PCB background level (460 µg/kg [0.46 parts per million, ppm]) are documented in Appendix II, Tables 25 and 26, respectively, of the ROD for the lower 8.3 miles of the LPRSA (dated March 3, 2016).

3.1.3 Discussion of the RAOs

The overall objective of an IR in the upper 9 miles of the LPRSA is to eliminate or mitigate the most significant sediment sources of 2,3,7,8-TCDD and total PCBs above RM 8.3.[40] In doing so, an IR will eliminate elevated contaminant concentrations (and reduce average contaminant concentrations) of these two contaminants, thereby eliminating the potential mobilization of elevated concentrations of the two contaminants to other areas of the LPRSA, accelerating recovery, and reducing exposure to biota.

In this IR FS, remedial footprints evaluated for each remedial alternative (other than the No Action alternative) are delineated to meet both RAO 1 and RAO 2.[41] The post-IR SWACs of 85 ng/kg of 2,3,7,8-TCDD and 0.46 mg/kg of total PCBs specified in RAO 1 are expected to be achieved at the completion of an interim remedial action.

RAO 2 addresses areas that are not targeted by RAO 1 but have a reasonable likelihood of erosion occurring and exposing subsurface concentrations, thereby elevating the 2,3,7,8-TCDD and/or total PCB SWAC from RM 8.3 to RM 15. These areas have the following characteristics: 1) they are erosional; 2) there is a reasonable likelihood that erosion would expose sediment 6 in. or more below the current sediment surface; and 3) that sediment, if exposed, has subsurface 2,3,7,8-TCDD and/or total PCB concentrations above the subsurface RALs. For the IR FS, areas with these characteristics are identified and included in the remedial footprint, as described in Section 7.2.

In the remedial design, it is anticipated that erosional areas will be primarily evaluated using observed changes based on available bathymetric data. In the event that it is required to support the bathymetric analysis (e.g., the current model grid is too coarse to sufficiently capture spatial changes in bathymetry impacting erosional behavior), a high-resolution hydrodynamic model of high flow event shear stresses conducted during the remedial design, coupled with erosion parameters established for the LPRSA sediment transport modeling, could be used. In the erosional areas, pre-design sediment sampling will characterize subsurface sediment concentrations of 2,3,7,8-TCDD and total PCBs within the depth interval of potential erosion and will support IR design (note that pre-design surface and subsurface sediment sampling will be performed throughout the upper 9 miles of the LPRSA, and not only in erosional areas, as described further in Section 7.1.6).

Appendix H presents a detailed framework outlining the data requirements, lines of evidence, and decision process to evaluate the attainment of RAOs 1 and 2 following completion of an IR

[40] While this IR FS focuses on a potential IR addressing areas of elevated 2,3,7,8-TCDD and total PCB concentrations, other contaminants of concern will be addressed to the extent they are collocated (see RI, Section 4, AQEA 2019). All site risks will be addressed in future decision documents for the LPRSA.
[41] An additional alternative, delineated to achieve a post-IR 2,3,7,8-TCDD SWAC of 125 ng/kg, was evaluated for comparative purposes.

and to support EPA's administrative determination of IR project completion. If an IR is selected, the approach to achieve the RAOs will be further developed and refined during the remedial design.

4 ARARs

CERCLA Section 121(d) requires that remedial actions either comply with or have been granted a waiver from ARARs. An ARAR is defined as a legally applicable or relevant and appropriate standard, requirement, criterion, or limitation under any federal environmental law, or promulgated under any state environmental or facility siting law that is more stringent than the federal law. An ARAR may be either "applicable" or "relevant and appropriate," but not both, as these terms are defined in the NCP.

TBC information consists of non-promulgated criteria, advisories, guidance, and proposed standards that are issued by federal or state governments. Although TBCs are not potential ARARs because they are neither promulgated nor enforceable, it may be necessary to consult TBCs to interpret ARARs or to determine PRGs when ARARs do not exist for particular contaminants or if ARARs may not be sufficiently protective. Compliance with TBCs is not mandatory. Examples of TBC criteria include those in the NJDEP (1997) dredging technical manual and related best management practices (BMPs).

4.1 GENERAL REQUIREMENTS

Unless an ARAR is waived, the NCP requires that remedial actions comply with ARARs. For this reason, ARARs are a key consideration in the development of RAOs. In cases where ARARs prescribe binding numeric criteria, standards, or cleanup requirements for environmental media, ARARs may become the basis for establishing numeric PRGs and final cleanup values.

EPA may waive an ARAR for a given response action provided that at least one of the following six specific conditions is met per CERCLA Section 121(d) and 40 CFR § 300.430(f)(1)(ii)(C):

1. The alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement.
2. Compliance with the requirement will result in greater risk to human health and the environment than other alternatives.
3. Compliance with the requirement is technically impracticable from an engineering perspective.
4. The alternative will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, or limitation through use of another method or approach.

5. With respect to a state requirement, the state has not consistently applied, or demonstrated the intention to consistently apply, the promulgated requirement in similar circumstances at other remedial actions within the state.
6. For Fund-financed response actions only, an alternative that attains the ARAR will not provide a balance between the need for protection of human health and the environment at the site and the availability of Fund monies to respond to other sites that may present a threat to human health and the environment.

There is more flexibility in the relevance and appropriateness determination than for an "applicable" determination: a requirement may be "relevant" in that it covers situations similar to those at the site, but may not be "appropriate" to apply for various reasons and, therefore, not well suited to the site. In some situations, only portions of a requirement or regulation may be judged relevant and appropriate (USEPA 1991b).

Another factor in determining which requirements must be addressed is whether the requirement applies to onsite or offsite elements of a CERCLA response action. Onsite CERCLA response actions must comply with the substantive requirements but not with the administrative requirements of environmental laws and regulations as specified in the NCP (40 CFR § 300.5, *Definitions of ARARs,* and as discussed in 55 Federal Register 8756 [March 8, 1990]). Substantive requirements are those pertaining directly to actions or conditions in the environment. Administrative requirements are mechanisms that facilitate the implementation of the substantive requirements of an environmental law or regulation. In general, administrative requirements prescribe methods and procedures (e.g., fees, permits, inspections, or periodic reports) by which substantive requirements are made effective for the purposes of a particular environmental or public health program.

An IR, if implemented, would be focused on sediment source control. The river-wide remedy for surface water will be selected as part of the final ROD for the LPRSA. Long-term (post-remediation) compliance with surface water ARARs or the potential need to seek a waiver would not be evaluated as part of the ROD for an IR.

4.2 IDENTIFICATION OF ARARS

ARARs are identified based on the remedial alternatives under evaluation and consideration of the following:

- Site knowledge and regulations that are anticipated to be triggered by the proposed alternatives
- Onsite vs. offsite location of the activity

- State regulation or delegated authority vs. federal regulation; a state regulation is an ARAR if it has been promulgated and is more stringent than federal rules
- River salinity regime and land use
- Applicability to the scope of a source control IR.

ARARs are grouped into three types: chemical-specific, action-specific, and location-specific. The potential ARARs for the LPRSA are presented in Tables 4-1 and 4-2.

4.2.1 Chemical-Specific ARARs

Chemical-specific ARARs include laws and requirements that establish health- or risk-based numerical concentration limits or assessment methodologies for chemical contaminants in environmental media or effluents. No chemical-specific ARARs exist for sediment in the LPRSA, because there are no federal or state-promulgated standards for contaminant levels in sediment.

4.2.2 Action-Specific ARARs

Action-specific ARARs define acceptable approaches for managing all environmental requirements of the remedial action (e.g., upland staging facility, treatment and disposal procedures for hazardous substances). They generally set performance, design, or other similar action-specific environmental controls or restrictions on particular kinds of activities related to implementing the remedial action and managing hazardous substances or pollutants. These requirements are triggered by the remedial activities selected to accomplish a remedy. Different action-specific requirements may apply to the remedial alternative actions under consideration in the IR FS. Table 4-1 summarizes the potential action-specific ARARs for the LPRSA.

4.2.3 Location-Specific ARARs

Location-specific ARARs are requirements that relate to the geographic position of the site. State and federal laws and regulations that apply to the protection of wetlands, construction in floodplains, and protection of endangered species in streams or rivers are examples of location-specific ARARs. Table 4-2 summarizes the potential location-specific ARARs for the upper 9-mile IR.

5 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section identifies and screens remedial technologies that could potentially be used to meet the upper 9-mile IR FS RAOs presented in Section 3. The process for identification and screening of remedial technologies and process options is consistent with the EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (USEPA 1988).

The identification and screening process is a step-wise approach considering general response actions (GRAs), technology types, and process options that are potentially applicable to the IR cleanup of contaminated sediment in the upper 9 miles of the LPR. These three categories or tiers provide a systematic method to identify and evaluate various physical, chemical, and administrative "tools" available for implementing remedial actions.

GRAs describe in broad terms the types of actions potentially applicable to cleanup of contaminated media. Each GRA may contain one or more technology types. For example, one GRA is the physical removal of contaminated sediment from the site, and two common technologies that can accomplish this sediment removal are dredging and excavation. Process options are a further subdivision in the technology screening procedure, and define the specific method or type of equipment used within a technology. For example, dredging may be accomplished using process options such as clamshell dredging or hydraulic dredging.

The GRAs identified in this FS include:

- No action
- Institutional controls
- Natural recovery
- *In situ* sediment treatment
- *Ex situ* sediment treatment
- Containment
- Sediment removal
- Transport of sediment and capping materials
- Disposal
- Beneficial use.

Consistent with EPA guidance (USEPA 1988), the following sections identify and screen potentially applicable remedial technologies and process options corresponding to the above

GRAs. A summary of the screening of technologies and process options is presented in Table 5-1. Process options determined to be representative, effective, and implementable are retained and carried forward into the development of remedial alternatives, as described in Section 7.

5.1 EVALUATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

This screening of potentially applicable remedial technologies and process options considers information from recent regional and national sediment remediation projects. The screening also considers EPA's evaluation in the OU2 FFS (LBG 2014a) and pilot/treatability studies performed by EPA (LBG 2014a; USEPA 2012b; BioGenesis 2009; GTI 2008) and the CPG (CH2M Hill 2012, 2013), as well as lessons learned from early actions on the LPR (see Appendix E). Published guidance and resources such as the Superfund Innovative Technology Evaluation Program, the EPA Hazardous Waste Cleanup Information website, and the Federal Remediation Technologies Roundtable were also referenced.

In accordance with EPA guidance, this screening evaluation considers effectiveness, implementability, and cost of the candidate process options. Effectiveness refers to whether a process option can address the contaminated media types and quantities, supports achievement of the RAOs, and is proven and reliable. Implementability refers to whether a process option can be constructed and operated under the physical and chemical conditions of the upper 9 miles of the LPR, is commercially available, is administratively feasible, and has been used on sites similar in scale and scope to the upper 9 miles of the LPR. Cost refers to the cost of a process option relative to other process options for a given technology type.

The following sections provide a description, evaluation, and screening of the remedial technologies and process options considered in this screening. A summary of the screening results is presented in Table 5-1. This screening does not preclude reexamination of technologies during the remedial design phase. Rather, the screening facilitates a streamlined approach to the development and evaluation of remedial alternatives. Accordingly, the following terminology is used to describe the screening results:

- **Retained.** Remedial technology/process option is retained and incorporated into the remedial alternatives as a representative technology/process type.
- **Retained for further evaluation during remedial design.** Remedial technology/process option is considered to be potentially effective and implementable and may warrant further consideration during remedial design, but has not been incorporated into the remedial alternatives in this FS.

5.1.1 No Action

Under a no-action response, no removal, containment, treatment, engineering controls, or new institutional controls are implemented. A no-action response may include maintenance of existing institutional controls and provisions for conducting 5-year reviews required by CERCLA Section 121(c).

The NCP requires that no action be considered as a potential remedial action for comparative purposes and therefore has been **retained**.

5.1.2 Institutional Controls

Institutional controls refer to non-engineering measures intended to ensure the protectiveness of the remedy and to affect human activities and ecological receptors to prevent or reduce the potential for exposure to contaminated media. Institutional controls can play an important role when remediation to attain final RGs through active measures is impractical or not cost-effective relative to similarly protective cleanup options (USEPA 2000b). Potentially applicable institutional controls for the upper 9 miles of the LPR can be grouped into the following technologies:

1. Government controls—include regulations to restrict waterway use
2. Proprietary controls—include property use restrictions based on private property law
3. Informational devices—include deed notices or public advisories that alert and educate people about a site.

Institutional controls are commonly applied at sediment cleanup sites and can be effective and implementable in combination with active remedial elements and appropriate monitoring, and are, thus, **retained** for this IR FS. The IR FS assumes that existing institutional controls (e.g., fish advisories) will remain in effect during and, as necessary, following the IR. The following sections discuss applicable technologies and their respective process options.

5.1.2.1 Governmental Controls

Governmental controls impose restrictions on land or resource use, with the authority of a government entity.

For a sediment cleanup, a commercial fishing ban may be implemented to restrict harvesting and consumption of fish and seafood. Other governmental controls may be implemented to protect the integrity of the remedy or a specific remedy element by prohibiting activities that could disturb or otherwise compromise its performance. Under the CFR (22 CFR Part 165), a regulated navigation area (RNA) may be established to regulate vessel navigation within a

defined boundary. Example RNA restrictions include limitation on anchoring, spudding, or grounding vessels in cap areas.

5.1.2.2 Proprietary Controls

A proprietary control is a private contractual mechanism contained in the deed or other document transferring the property. On privately owned lands, restrictive covenants (a form of proprietary controls) can be effective in maintaining the long-term integrity of capping or other containment actions, and can be used to help control exposure scenarios (e.g., residential versus recreational uses of land). Proprietary controls may be required for siting of upland facilities that are part of the remedy and/or remedy components such as capped areas within private or publicly owned, leased, or used in-waterway lands (i.e., tidelands or riparian grant lands). For the purposes of this screening, such proprietary controls are referred to as "land use restrictions."

5.1.2.3 Informational Devices

Informational devices include deed notices or public advisories that alert and educate people about a site.

Deed Notices

A deed notice could be filed and recorded that would describe restrictions on the property to protect the cap and could remain in effect until the federal or state government states in writing that a change in site condition(s) warrants its removal.

Fish and Crab Advisories

Fish and crab consumption advisories are an institutional control subject to informed voluntary compliance by the public. There is currently an NJDEP fish and crab consumption advisory for the LPR (Dundee Dam to Newark Bay).[42] This advisory recommends restrictions on consumption of fish and shellfish, and bans on collection of blue crabs from the entire LPR (NJDEP/NJDOH 2019). This screening assumes that the advisory will remain in effect during and, as necessary, following the IR. Possible modifications to this advisory would be reviewed and evaluated throughout the IR, based on long-term performance monitoring data.

Signage

Signs to warn vessel operators of critical remedy area boundaries (e.g., sediment caps) could be installed to provide added protection and notify vessel operators of applicable RNA restrictions. Signage could also be used to warn vessel operators and other potential proximate users of the site risks and provide information about pertinent advisories.

[42] https://www.nj.gov/dep/dsr/Fish_Advisories_2019.pdf

5.1.3 Natural Recovery

Natural recovery of sediment refers to the ability of natural processes such as chemical and biological degradation, as well as physical burial by incoming sediment, to reduce COC concentrations and exposure over time. Where conditions support natural recovery and natural recovery is included in the remedial alternative, monitoring will be employed (i.e., monitored natural recovery, MNR) to assess if, and at what rate, risks are being reduced and whether progress is being made toward achieving the IR objectives. Enhanced natural recovery (ENR) involves the application of thin layers of clean granular material (e.g., sand) to the sediment surface producing an immediate reduction in surface COC concentrations, thereby accelerating the recovery process relative to what is possible by relying solely on natural sediment deposition. The following sections assess the applicability of MNR and ENR for sediment in the upper 9 miles of the LPR.

5.1.3.1 Monitored Natural Recovery

MNR is a risk management approach that relies on natural environmental processes to permanently reduce exposure and risks associated with contaminated sediment, and is a common remedial element for large, complex sediment sites. MNR can be effective both for management of residual contamination outside of the active remedial zones and as a temporal phase in a remediation approach. The environmental processes include chemical and biological degradation as well as physical burial via deposition, bioturbation, and surficial mixing. Natural recovery may not be effective in areas subject to periodic or continuous erosion, or in non-depositional areas. Institutional controls, such as fish consumption advisories, are typically applied in conjunction with MNR to control human exposure during recovery periods (USEPA 2005). A long-term monitoring program is a key component of MNR and may include physical surveys as well as chemical and biological sampling to assess the extent to which ongoing natural recovery occurs. MNR requires the development of well-defined goals, performance metrics, and baseline conditions.

MNR is considered an implementable process option in the upper 9 miles of the LPR. MNR would be evaluated during recovery assessment monitoring following completion of an IR. The conceptual model of natural recovery is summarized in Section 2 and presented in detail with supporting evaluations in the RI (AQEA 2019).

MNR has been demonstrated to be effective and implementable at other sediment sites and is potentially applicable in upper 9-mile areas with favorable conditions for recovery (e.g., low-scour potential, net depositional conditions) and thus, has been **retained**.

5.1.3.2 Enhanced Natural Recovery

ENR involves the placement of a thin layer of clean sand or fill material over areas to speed up or enhance the natural recovery processes already demonstrated to be occurring at a site. ENR is applicable to areas that exhibit net sedimentation. The clean layer is typically about 6 in. thick and produces an immediate reduction in surface contaminant concentrations. ENR may be useful in proposed dredging and/or capping areas with access constraints or where disturbance of the sediment represents a risk to adjacent structures or buried utilities. ENR would need to be designed and implemented in a manner that does not result in increased flood hazards. Such hazards could be offset by designing nearby dredging and sediment cap grades so as to avoid a net increase of fill placement within the waterway or using thin layers that would mix with the existing sediment bed with minimal or no change in bed elevation. ENR requires the development of well-defined goals and performance metrics.

ENR is considered a potentially effective and implementable option for sediment in the upper 9 miles of the LPR, to address dredge residuals, access-constrained areas (e.g., under piers, near critical subsurface or shoreline structures), or other areas that exhibit favorable conditions for recovery (e.g., low-energy, low-scour potential, net depositional, biologically active). Therefore, ENR is **retained for further evaluation during remedial design**.

5.1.4 *In Situ* Sediment Treatment

In situ sediment treatment technologies rely upon sequestering agents (such as activated carbon and other treatment media), biological or chemical degradation, and fixation to reduce sediment contaminant availability and mobility. It has been demonstrated that when mixed with *in situ* sediment, activated carbon can reduce the bioavailability of a range of contaminants, including PAHs, PCBs, dioxins/furans, DDT, and mercury (Ghosh et al. 2011).

Activated carbon materials may be placed by tilling, injection, and broadcasting over the water surface. Premixing activated carbon with sand has been used at many sites. There are also proprietary products that combine powdered activated carbon (PAC) with a heavier core particle and binding agents to produce a particulate material that can be placed like sediment or capping materials. Examples include Sedimite™, AquaBlok®, and AquaGate+PAC™. Another type of amendment used for *in situ* treatment is Organoclay™, which is less sorptive than activated carbon, but can also reduce the bioavailability of nonsoluble organics and other contaminants (Sarkar et al. 2000). Organoclay™ is recognized for its effectiveness in immobilization of nonaqueous-phase liquids.

The applicability and type of amendment is determined during design and considers contaminant concentrations in the sediment and pore water, hydrodynamic and sediment stability conditions, and long-term performance requirements. Example projects with demonstrated success using *in situ* application of activated carbon include 2,3,7,8-TCDD,

mercury, and PCBs (among other contaminants) at the LPRSA RM 10.9 removal action (CH2M Hill 2019); PCBs, mercury, and PAHs at the Mirror Lake remediation and restoration, Delaware (USEPA 2015); PCBs at the Puget Sound Naval Shipyard, Washington (ESTCP 2017); PCBs at Grasse River in Massena, New York (Ghosh 2010); PCBs at Hunter's Point Naval Shipyard in San Francisco, California (ECC Insight et al. 2017; Ghosh et al. 2011; Luthy et al. 2009); PCBs and mercury at Aberdeen Proving Ground in Maryland (Menzie 2011); and PCBs at a U.S. Army Installation in Virginia (Menzie 2011).

In situ treatment (e.g., sequestration amendments) is considered to be a potentially effective option to improve conventional cap performance (if needed), for bulk application in access-constrained areas in conjunction with ENR strategies (e.g., under piers/bridges, near bulkheads, utility crossings), or other areas that exhibit favorable conditions for recovery using this technology and is therefore **retained for further evaluation during remedial design**. Selection of reactive materials may require bench- or pilot-scale studies to demonstrate effectiveness in the upper 9 miles of the LPR.

5.1.5 *Ex Situ* Sediment Treatment

Ex situ treatment involves the application of technologies to transform, destroy, or immobilize contaminants following removal of sediment. The applicability of *ex situ* treatment to the LPRSA was evaluated by the CPG for the RM 10.9 removal action (CH2M Hill 2013) and by EPA in the OU2 FFS (LBG 2014a). Process options evaluated included soil washing, solidification/stabilization, and thermal treatment. The only technologies that have been used for LPR removal actions to date are stabilization and thermal treatment (i.e., incineration). Stabilization was used for improving sediment handling and transport characteristics for the RM 10.9 removal action (CH2M Hill 2019). Incineration was used for a small portion of material classified as hazardous during the Phase 1 removal action (Tierra 2013). The following sections provide a brief summary of *ex situ* treatment technologies previously evaluated for the upper 9 miles of the LPR.

5.1.5.1 Soil Washing

Soil or sediment washing is performed *ex situ* on dredged material and is a water-based contaminant volume reduction process similar to the soil washing techniques used in the mining industry. During this process, sediment particles are physically separated using conventional equipment and contaminants are extracted and concentrated into a small residual portion of the original volume using physical and chemical means (USEPA 2005).

In the development of remedial alternatives for the OU2 FFS (LBG 2014a), EPA identified vendors who have developed sediment washing technologies. In 2005–2006, EPA conducted a sediment washing pilot study using a technology with the trade name of BioGenesis™ (BioGenesis 2009). The results of this study were inconclusive with respect to the ability of

BioGenesis™ to effectively reduce COC levels to New Jersey standards, which would allow the end product to be used beneficially without restrictions. EPA concluded that it was possible that sediment washing, combined with solidification/stabilization technology, may enable the end product to be used as landfill cover at a municipal (Resource Conservation and Recovery Act [RCRA] Subtitle D) landfill (LBG 2014a; USEPA 2012b).

In August 2012, a second evaluation of soil washing was performed on RM 10.9 sediment. In this study, bench-scale sediment washing tests were performed by two sediment washing vendors (BioGenesis™ and Pear Technology). Neither was able to achieve the beneficial use criteria for dioxins/furans, PCBs, and PAHs. These results are summarized in RM 10.9 Removal Action—Sediment Washing Bench-Scale Testing Report, Lower Passaic River Study Area—CERCLA Docket No.02-2012-2015 (CH2M Hill 2012) and Appendix H of River Mile 10.9 Removal Action Draft Final Design Report, Lower Passaic River Study Area (CH2M Hill 2013). The RM 10.9 evaluation showed that the treated sediment would not be suitable for beneficial use and would need to be further treated or disposed of at a permitted landfill (CH2M Hill 2013). Based on these findings, soil washing was deemed technically and economically nonviable for the RM 10.9 removal action. Prior studies at other sediment sites in the U.S. have identified similar limitations.

Despite findings from two previous LPRSA pilot studies, the absence of demonstrated success on projects of similar scale at other sites, and other considerations noted above, soil washing is **retained for further evaluation during remedial design**. Further testing would be required to demonstrate that the technology could achieve IR cleanup criteria required for beneficial use.

5.1.5.2 Stabilization

Stabilization is applied *ex situ* to reduce the mobility of hazardous constituents in a contaminated material. Stabilization methods typically involve amending dredged materials with agents such as cement, quicklime, grout, or pozzolanic materials, as well as other reagents. Sediment generally requires some preprocessing, such as screening of oversized material, prior to stabilization.

This technology is widely used to improve the handling characteristics of the sediment for offsite transportation for disposal or placement. The effectiveness of stabilization technologies varies depending on the characteristics of the contaminated sediment and the particular additives used.

For the RM 10.9 removal action, stabilization using Portland cement was applied to dredged materials at the processing facility prior to transportation to the offsite disposal facility. Bench-scale testing of representative sediment would also need to be performed to determine the type and amount of stabilizing agent to be added to meet disposal requirements (e.g., strength requirements and the desired reduction in contaminant leachability).

Based on its demonstrated success on prior LPRSA projects, sediment stabilization is considered to be an effective and implementable process option and thus is **retained**.

5.1.5.3 Thermal Treatment

Ex situ thermal treatment technologies include thermal desorption, thermal destruction, incineration, and vitrification. These thermal treatment process options are discussed further below.

Mobile treatment operations and brick-and-mortar facilities exist for each process option. A mobile treatment operation would reduce transportation costs, time lag between removal and disposal, and subsequently, duration of exposure of workers and the public, compared to a brick-and-mortar facility. If a mobile incinerator were combined with local beneficial use, transportation of thermally treated sediment would be further reduced. The drawbacks of a mobile treatment system are the capacity limitations of the mobile unit, space limitations on- or near-site for stockpiling sediment, and the potential for construction shutdown due to incinerator malfunction (e.g., if a replacement part must be shipped), which would be exacerbated by the proposed 24-hour-per-day operation. The availability and suitability of mobile treatment options for the IR may be further evaluated during remedial design as a treatment alternative.

Thermal Desorption

Thermal desorption involves the heating of dredged sediment to levels below combustion to volatilize or desorb organic contaminants (and can partially remove certain metals [e.g., arsenic, mercury] at sufficient temperatures) for later capture and/or destruction. Air emissions are controlled via treatment in a secondary unit. The water stream resulting from the associated condensation process may require further treatment. Thermal desorption systems are generally effective for destroying a broad range of organic compounds. Metals are not destroyed by thermal desorption systems. Highly organic and fine-grained soils increase reaction time as a result of binding of contaminants, high plasticity, and high moisture content.

Thermal desorption has been demonstrated as effective at other sediment remediation sites. However, a large proportion of the sediment in the upper 9 miles of the LPR is highly organic, fine-grained and contains heavy metals. Because these characteristics increase reaction time and thermal desorption does not treat heavy metals, thermal desorption is not likely to be effective, but has been **retained for further evaluation during remedial design**.

Thermal Destruction

Thermal destruction is a controlled process that uses high temperatures (typically between 1,400 °F and 2,200 °F) to volatilize and combust organic chemicals. Air emissions are controlled via air treatment. Thermal destruction technology has been demonstrated to be effective in

destroying organic contaminants, similar to those present in sediment of the upper 9 miles of the LPR.

This technology has been studied and proven effective for destroying organic contaminants in two regional demonstration projects. From 2003 to 2006, this technology was tested at the pilot-scale level for approximately 350 cy of sediment dredged from the Stratus Petroleum site in Upper Newark Bay. This demonstration project successfully achieved applicable cleanup goals, but the equipment experienced problems and the project was eventually shut down (GTI 2008). In 2006–2007, a demonstration thermal destruction treatment plant was set up in Bayonne, New Jersey, for a pilot study of the Cement-Lock® thermo-chemical process on 16.5 tons of LPR sediment. The results of this study showed that this process was more than 99.9 percent efficient at treating dioxins/furans and PCBs in LPR sediment. The beneficial use product of this process is construction-grade cement in which the nonvolatile metals originally present in the sediment are bound. The Cement-Lock® product passes the toxicity characteristic leaching procedure (TCLP) test for priority pollutants. However, the feasibility of a full-scale operation remains uncertain.

Despite economic and implementation uncertainties associated with this technology and issues surrounding beneficial use of the residual material, thermal destruction is **retained for further evaluation during remedial design** because it is one of the only technologies demonstrated to be effective in treating the organic and inorganic COCs detected in the sediment of the LPR. However, the selection of this process option would be contingent on identifying an economically viable end user for the treated product and securing release and indemnification of the performing parties against liability for any residual contamination in the treated product.

Incineration

Incineration is a thermal treatment technology that destroys organic contaminants. Incinerators operate at 1,600 °F to 2,500 °F and generate large amounts of ash. Generated ash can generally be disposed at a Subtitle C landfill. This technology has a high energy consumption. Incineration is not effective for removal of heavy metal contamination. This treatment process may increase leachability of metals through oxidation. Air pollution control systems are required to remove metals that may volatilize during incineration (e.g., mercury). The primary risk for air pollution is incomplete combustion causing the escape of organic compounds.

In the upper 9 miles of the LPR, sediment may be identified as RCRA characteristic waste and require incineration to meet land disposal requirements. RCRA characteristic waste must be treated for all "underlying hazardous constituents" including dioxins, which can only be treated by incineration.

Incineration has demonstrated effectiveness and is commercially available. The nearest existing, permitted incineration facility, a Clean Harbors thermal desorption unit facility in Ontario, Canada, is more than 500 miles from the site.

Incineration is **retained for further evaluation during remedial design** because it is one of the only technologies demonstrated to be effective in treating potential RCRA characteristic waste.

Vitrification

Vitrification is a thermal treatment technology that employs high energy to melt sediment at extremely high temperatures (2,900 °F to 3,650 °F) into a glass aggregate product. Inorganic compounds are incorporated into the vitrified glass and crystalline mass and organic pollutants are destroyed by pyrolysis. The glass end product may be beneficially used in construction.

Although vitrification has been demonstrated by a vendor through bench-scale applications on contaminated sediment (Minergy 2004), there are currently no known pilot studies or commercially available full-scale operating facilities. For application to the sediment of the upper 9 miles of the LPR, the economic feasibility of implementing this energy-intensive technology is considered low. This process option is **retained for further evaluation during remedial design**.

5.1.6 Containment

Sediment capping is a potentially applicable containment technology with well-established precedence and design guidance (Palermo et al. 1998a). Common cap types include engineered granular caps, composite caps, and reactive caps. The primary functions of a cap are (Palermo et al. 1998b):

- Physical isolation of the contaminated sediment from human and ecological receptors
- Stabilization of contaminated sediment and the prevention of resuspension and transport to other areas
- Reduction of the flux of dissolved contaminants into the water column.

For the purposes of the IR FS, it is generally assumed that all capped areas would be pre-dredged and designed to result in no net loss of water depth and/or increase in flooding potential. Typical cap configurations may include sand, armoring, geotextile, and reactive layers and are discussed in greater detail in the following sections.

5.1.6.1 Engineered Cap

Conventional caps are typically constructed of clean sand and or/gravel and provide physical isolation of contaminated sediment from the overlying waterway. Conventional cap design takes into account natural and anthropogenic erosive forces, current and future navigational needs, and biological processes. Conventional sand capping is a proven technology, is considered effective and implementable, and is therefore **retained** for the IR FS.

5.1.6.2 Armored Cap

To reduce erosion of cap material by high river flows and other erosive forces, a conventional sand cap may also include a layer of rock armoring. Armor can be a component of any other type of cap. An armored cap typically consists of a sand cover and other structural elements (such as stone armor) to provide resistance to erosive forces. To prevent disruption of a cap by hydrodynamic forces, EPA guidance indicates use of 100-year return period flood for design (USEPA 2005). Armor is an effective, easily implementable, and proven technology and is **retained**, as a component of an engineered cap, for the IR FS.

5.1.6.3 Composite Cap

A composite cap consists of multiple layers, and may include sand, geotextiles, reactive amendments, and armoring. As in conventional cap design, composite caps include a sand layer for physical isolation of contaminated sediment and the overlying water column. Sand thickness may be less in composite caps depending on the properties of other layers (e.g., geotextile or high-density polyethylene). A layer of cobble or other armoring material may be applied to the top layer of a composite cap in scour areas. A composite cap is an effective, easily implementable, and proven technology and is **retained for further evaluation during remedial design**.

5.1.6.4 Reactive Cap

Placement of reactive materials within a cap can serve to sorb and sequester contaminants, preventing contaminant flow to the overlying water column. Reactive cap amendments may be placed in bulk form as separate layer or mixed with the sand layer. Reactive amendments may also be encapsulated and deployed within a geotextile product. Addition of reactive layers allows for a thinner cap as the amendments increase adsorptive capacity and extend the breakthrough time (time for contaminants to flow from the underlying sediment through the cap into the overlying water column). Available active cap amendments include activated carbon and Organoclays™ as well as engineered products such as AquaGate™ composite particles (developed by AquaBlok). One of the first implemented reactive sediment caps dates to 2002, when granular activated carbon was incorporated into the sand cap in the Olympic View Resource Area in Washington (ITRC 2014). More recently, reactive caps have documented success at multiple sites, including the Spokane River in Washington and the McCormick & Baxter creosote site in Oregon (USEPA 2013c).

Reactive capping with AquaGate+PAC™ was implemented for the RM 10.9 removal action. A treatability study was performed as part of the remedial design at RM 10.9 using site-specific sediment to evaluate the performance of activated carbon, organoclay, or an engineered mixture of those materials as the active cap layer. The final cap design included armoring, a geotextile

stabilization layer, and an active cap layer consisting of 25 percent AquaGate+PAC amendments mixed with 75 percent sand (CH2M Hill 2019).

Composite and reactive caps are considered effective and implementable, have demonstrated success within the LPRSA and other sites, and are thus **retained for further evaluation during remedial design**.

5.1.7 Sediment Removal

Removal is a common and frequently implemented GRA for sediment remediation nationwide. Mechanical dredging, specialty dredging, hydraulic dredging, and excavation using land-based equipment (dry excavation) are the four representative process options available for removing contaminated sediment.

Sediment removal to be performed as part of an upper 9-mile IR would be completed, at a minimum, to the depths necessary to accommodate capping and is **retained** for the IR FS.

Dredging without capping (i.e., dredging to clean sediment) is **retained for further evaluation during remedial design** in areas where the PDI indicates conditions that may support its use (see Section 7.1.1 for a discussion of principles for consideration of dredge to clean in the IR FS). The potential feasibility, efficacy, and protectiveness of dredging without capping will be further evaluated in the remedial design when sufficient data are available.

5.1.7.1 Mechanical Dredging

A mechanical dredge typically consists of a suspended or manipulated bucket that bites into the sediment and raises it to the surface via a cable, boom, or ladder. The sediment is deposited on a haul barge or other vessel for transport to a processing/transloading facility or disposal site.

Mechanical dredging tends to entrain less water than hydraulic dredging (described below) by maintaining much of the *in situ* sediment structure, with a typical water entrainment ratio of approximately two parts water to one part dredged sediment. As a result, upland sediment processing and water treatment facilities generally require less acreage to handle mechanically dredged sediment than hydraulically dredged sediment.

Clamshell buckets (open, closed, hydraulic-actuated), articulated fixed-arm (backhoe), dragline buckets, dipper (scoop) buckets, and bucket ladders are all examples of mechanical dredges. Clamshell dredges work best in water depths less than 100 ft to maintain production efficiency. Clamshell "digging" buckets are most effective in consolidated sediment and where debris is present. Nominal dredge bucket capacities typically range from 1 to 10 cy.

Environmental buckets, or specialty level-cut buckets, offer the advantages of a large footprint, a level cut, and the capability to remove even layers of sediment. A level-cut bucket reduces the

occurrence of ridges and winnows that are typically associated with conventional clamshell buckets. Environmental buckets are effective in unconsolidated sediment. They are not as effective when digging consolidated sediment or where a significant amount of debris may be present.

An alternative to a conventional clamshell dredge is a barge-mounted precision excavator. The excavator is equipped with an articulated, hydraulic, fixed-arm precision bucket. The excavator makes its desired cut utilizing hydraulic pressure, without relying on the weight of the bucket for penetration. This dredging method is generally restricted to shallower operational dredging depths than conventional clamshell dredges (up to approximately 50 ft) and has a lower production rate than mechanical dredging due largely to limitations in bucket capacity (USEPA 1994).

Mechanical dredging has been demonstrated as an effective and implementable technology through broad application at similar sediment sites across the country, including two recent removal actions within the LPRSA (CH2M Hill 2019; Tierra 2013). It is well suited to digging consolidated sediment deposits and handling debris that exists in the upper 9 miles of the LPR and thus, is **retained** as the representative technology process option for sediment removal.

5.1.7.2 Specialty Dredging

Specialty dredging technologies are designed for small scale removal in areas that are challenging for conventional dredging technologies, such as adjacent to and underneath in-water structures. Specific technologies include Mud Cat (auger dredge head) and Sed-Vac (vacuum loader). Specialty dredging can also be diver-guided for precision.

Specialty dredging technologies are available and demonstrated technologies that are implementable for focused, small-scale removal. Specialty dredging is **retained for further evaluation during remedial design**.

5.1.7.3 Hydraulic Dredging

Hydraulic dredges remove and transport dredged material as a pumped sediment water slurry. Large debris is typically removed by clamshell buckets prior to hydraulic dredging. Sediment is dislodged into the water column by mechanical agitation, cutter heads, augers, or high-pressure water or air jets. In very soft sediment, it may be possible to remove surface sediment by straight suction or by forcing the intake into the sediment without first mechanically dislodging the sediment. The majority of the loosened slurry is then captured by suction from pumps into an intake pipe and transported through a dredge discharge pipeline to a handling/dewatering facility.

Hydraulic dredging typically entrains 8 to 10 parts water to 1 part dredged sediment, and requires substantial ancillary upland area facilities to dewater the sediment and to treat the

wastewater before discharge. High levels of debris can impede and/or damage a hydraulic dredge, potentially resulting in reduced efficiency, greater resuspension into the water column, and generation of greater amounts of process water, and require adjunct mechanical dredging to remove debris.

High levels of debris, sediment characteristics, and large-scale dewatering and water treatment requirements may limit the applicability of hydraulic dredging in the upper 9 miles of the LPR. Hydraulic dredging is, thus, **retained for further evaluation during remedial design**.

5.1.7.4 Land-Based Excavation

Land-based excavators may be used to remove shoreline and near-shore intertidal sediment under low-tide (exposed) conditions. Temporary barriers, such as sheet piles, combined with subsequent dewatering, can be used to facilitate removal in the dry in otherwise submerged areas. This method allows the excavation to be conducted "in-the-dry," facilitating better visual control and oversight of the work and reducing sediment dewatering requirements. Key considerations for this method are access requirements for equipment to/from the intertidal areas and construction sequencing requirements to accommodate daily tide cycles if applicable.

Land-based excavation methods have been demonstrated as an effective and implementable option at other sediment sites and have thus been **retained**, particularly for the uppermost reaches of the waterway where access constraints may preclude cost-effective removal using barge-based dredging and transport methods.

5.1.8 Transport of Sediment and Capping Materials

Dredged sediment can be transported from the point of removal to upland processing and transloading facilities using barges, hydraulic pipelines, or a combination of these two methods. Trucks and roll-off containers could support land-based excavation. Rail could transport dewatered sediment from upland processing facilities to the disposal site. The following sections discuss the potential applicability of these technologies to an upper 9-mile remedial action.

5.1.8.1 Mechanical Transport

Barges are commonly used to transport mechanically dredged sediment from the point of removal to an upland processing facility. A barge would be positioned next to the mechanical dredge and direct loaded as the dredge removes sediment. Once full, the barge would be moved and replaced with an empty barge. A tugboat would then push or tow the loaded barge to the processing facility. Once the barge arrives at the processing facility, separated water would be decanted and the sediment would be mechanically offloaded and either directly

placed into the processing system or conveyed by other means to the processing system. Any decanted water from the barge would be treated (if necessary) prior to discharge.

Similarly, barges are commonly used to transport clean capping materials from riverside staging areas to the point of cap placement. Construction challenges associated with barge transportation are detailed in Section 7.1.9.

Mechanical transport also includes over-land transport in trucks, roll-off boxes, and rail. Land-based excavation may utilize trucks and roll-off boxes, as over-water transport options (barge and hydraulic transport) may not be able to access shallow areas where land-based removal is performed.

Rail is a proven and practical method of transportation for moving processed sediment to a disposal facility. Railcars were used to transport both Phase 1 and RM 10.9 sediment to a landfill after treatment. Landfills are typically served by rail lines, and commercial processing facilities often have access to rail lines, either at or nearby the treatment site. If a new processing facility were constructed, rail access would be a consideration for both facility siting and construction.

For the purposes of this FS, mechanical transport is **retained**. It is assumed that sediment from the upper 9 miles will be transported to the processing facility for dewatering and stabilization using barges and tugboats where possible, with truck and roll-off containers as an option where there are access constraints, and then the processed material will be transferred to railcars for shipment to a landfill. It is also assumed that all capping materials will be transported from one or more upland staging facilities via barge and tugboat.

5.1.8.2 Hydraulic Transport

Hydraulic transport of slurried sediment can be combined with either mechanical or hydraulic dredging. For hydraulically dredged sediment, slurried material can be immediately conveyed from the dredge area to the hydraulic pipeline, assuming debris has been removed in advance. For mechanically dredged sediment, a barge-mounted hopper would be positioned next to the mechanical dredge and directly loaded as the dredge removes the sediment. Before loading into the hopper, screening of sediment for debris and coarser materials would be performed to increase system efficiency and reduce maintenance on the pipeline and pumps. Screening would generate debris and coarse aggregate, requiring barge transport of that debris and aggregate to a facility for processing and/or disposal. Water would be fed into the hopper, and the resulting slurried sediment then would be pumped via pipeline to the processing facility.

Hydraulic transport requires significant consideration during design and construction of required pipeline lengths, boosters, potential right-of-way issues, and accommodation of vessel traffic.

Hydraulic transport of sediment is concluded to be feasible, but due to considerations associated with pipeline length, and accommodation of vessel traffic, it is anticipated to present a constraint for siting of potential processing facilities. Hydraulic transport is therefore **retained for further evaluation during remedial design**.

5.1.9 Disposal

A range of disposal options was previously evaluated for the LPRSA in association with the Tierra Phase 1 (Tierra 2008) and RM 10.9 (CH2M Hill 2013) removal actions, and by EPA in the OU2 FFS (LBG 2014a). Potentially applicable disposal options include confined aquatic disposal (CAD) facilities, CDFs, and permitted offsite landfill facilities. These disposal options are briefly summarized in the following sections.

5.1.9.1 Confined Aquatic Disposal

Disposal in a CAD facility involves subaqueous covering or capping of dredged material placed on the bottom or deposited in depressions or excavated pits at some on- or near-site aquatic location (USEPA 2005). CAD cells must be designed to prevent contaminant migration due to bioturbation, advective flux, and release of buried COCs. In addition, they must be engineered to withstand propeller and/or high-flow scour and natural phenomena such as hurricanes, tidal surges, and ice scour. CAD typically requires long-term monitoring to verify integrity of the cap and monitor recolonization of benthic infauna.

CAD facilities have historically been constructed in Newark Bay to support navigational dredging, but there are currently no available CAD sites to accept LPR sediment. Disposal of dredged material in open water CAD cells has been practiced for many years for both navigational and environmental dredging projects. A CAD cell has been used in Newark Bay by the U.S. Army Corps of Engineers (USACE) for NY/NJ harbor navigation dredging and deepening. After 15 years of use, the Newark Bay CAD facility was closed in 2012 after reaching capacity (USACE 2012a). Although future disposal of LPR sediment in this CAD facility is not viable, past use of CAD in Newark Bay demonstrates this technology is technically feasible and implementable. CAD has also been successfully implemented at other Superfund sites, including New Bedford Harbor (Apex 2017; USACE 1994).

Challenges to construction of a new CAD facility include potential environmental impacts, regulatory and public concerns, and lengthy site characterization and permitting processes. A CAD facility is a technically feasible, highly reliable, and cost-effective disposal option for the upper 9-mile remedial action. However, NJDEP has stated its opposition to the placement of a CAD facility in Newark Bay (NJDEP 2012). This option is not anticipated to receive state or community acceptance.

While it is anticipated that siting and permitting a CAD facility(ies) for the sediment of the upper 9 miles of the LPR would be difficult, this disposal process has proven effective at other sites including Newark Bay. CAD is therefore **retained for further evaluation during remedial design**.

5.1.9.2 Confined Disposal Facilities

CDFs are engineered structures enclosed by dikes mid-channel (i.e., islands) or extending from the shoreline. They are specifically designed to contain sediment (USEPA 2005). Untreated sediment is placed in the CDF cell, which is separated from the river by a physical barrier. CDFs include an engineered cap or cover over the cell. Similar to CAD cells, CDF cells must be designed to withstand contaminant migration due to advective flux and release of buried COCs. They must also be engineered to withstand natural phenomena such as hurricanes and tidal surges. CDFs require a long-term commitment to monitoring and maintenance to ensure long-term protection.

As with CAD facilities, there are many challenges with implementing this disposal option. Historically, public acceptance of CDFs has been very low. This option is not anticipated to receive state or community acceptance. Another key constraint for CDFs is identifying and obtaining approvals for a site that is proximal and of sufficient capacity to accommodate the potentially large volumes of impacted sediment.

Administrative challenges of this option include obtaining nearshore land access agreements from property owners. In addition, filling of nearshore lands would result in unavoidable loss of aquatic lands, presenting considerable permitting and habitat mitigation challenges. Implementation of CDFs would trigger ARARs for coastal, waterfront, and riparian zone development. CDFs also require permanent institutional controls (e.g., deed and land use restrictions, dredging moratorium) that may affect future development and uses of the disposal site.

In consideration of the noted technical and administrative constraints, CDFs will not be incorporated into FS alternatives but are **retained for further evaluation during remedial design**.

5.1.9.3 Offsite Landfill Disposal

Offsite landfills are widely used in regional sediment removal projects and are highly effective for long-term, permanent containment of contaminated materials. They are applicable to both large and small volume removals.

Dredged material for offsite disposal would be classified for disposal (i.e., hazardous or nonhazardous) based on RCRA regulations. Waste defined by RCRA as hazardous must be disposed of at a Subtitle C landfill, while nonhazardous waste may be disposed of at a

Subtitle D landfill, should the waste meet the facility-specific acceptance criteria. If PCB concentrations indicate Toxic Substances Control Act (TSCA) regulated sediment is encountered during dredging, then TSCA regulations would be followed (currently available data from the upper 9 miles do not suggest TSCA-regulated sediment is likely to be encountered). Testing will be performed to properly characterize the sediment for disposal, and all applicable disposal requirements will be met. Based on waste characterization conducted for the RM 10.9 removal, it was concluded that dredged sediment was not designated as a RCRA hazardous waste (CH2M Hill 2019; USEPA 2008c). Similarly, based on the results of analytical testing, including TCLP, all of the sediment waste derived from the CPG's sediment sampling programs (low-resolution coring, benthic, RM 10.9, etc.) has been classified as nonhazardous (CH2M Hill 2013; AECOM 2014; 2015a,b). The advantage of disposal at a Subtitle D landfill is lower transportation and disposal costs, assuming availability of local facilities. A Subtitle C landfill affords greater protection and may have less strict acceptance criteria. For this IR FS, it is conservatively assumed that all dredged sediment will be disposed at a RCRA Subtitle C landfill based on long-term liability considerations. During remedial design, sediment would be characterized for landfill acceptance and permitted landfills with capacity to receive dredged materials would be identified. Disposal of dredged material in existing permitted offsite landfills meets all state and federal requirements, uses reliable and demonstrated technologies, and can be readily implemented.

Based on prior EPA approvals of landfill disposal for Tierra's Phase 1 removal and RM 10.9 removal action, the IR FS assumes that upper 9-mile sediment will be placed in the Clean Harbors Lone Mountain Landfill in Waynoka, Oklahoma.

Given the sediment volumes anticipated to be removed during the IR, it is assumed that offsite disposal will rely on rail transport of material from the site to the disposal facility. Accordingly, the IR FS evaluation of landfill disposal options considered availability of rail access and railcars and the capacity of the regional rail system. The facility identified above is permitted to receive wet sediment (i.e., sediment that does not pass the paint filter test and therefore contains free liquid).

Offsite landfill disposal is a commonly applied disposal option for contaminated sediment, and is considered effective and implementable. Offsite disposal in a RCRA Subtitle C landfill is **retained** for assembly into remedial alternatives. Disposal in a RCRA Subtitle D facility has been **retained for further evaluation during remedial design**, and is contingent on a nonhazardous determination and facility-specific acceptance criteria for material impacted by chlorinated dioxins and furans.

5.1.10 Beneficial Use

This section provides a brief summary and evaluation of beneficial use as an alternative to landfill disposal, used in conjunction with treatment. As previously discussed, *ex situ* treatment

would likely need to be applied prior to beneficial use. Representative process options include sanitary landfill cover, construction fill, and mined lands restoration.

For more than a decade, EPA and the New Jersey Department of Transportation's Office of Maritime Resources, under a program initiated by the Water Resources Development Act, have implemented the New York/New Jersey Harbor Sediment Decontamination Technologies Demonstration Program, to investigate the use of decontamination technologies to produce environmentally acceptable beneficial use products from regional sediment. Full-scale studies conducted under the program demonstrated effectiveness in reducing organic and inorganic contaminants in regional sediment, including sediment collected from the LPRSA (USACE 2011). The program demonstrated potential cost/benefits of decontamination treatment technologies and was used by USACE to develop plans to beneficially use treated material during regional navigation dredging (USACE 2008a). However, a review of current literature and local knowledge did not provide examples of USACE's beneficial use of sediment that had been treated nor were examples of beneficial use of treated sediment from Superfund cleanups in the region identified.

The actual feasibility of this disposal option will depend upon a range of factors, including the physical and chemical characteristics of the sediment, the ability of treatment technologies to reduce contaminant concentrations to acceptable levels for intended use, the ability to identify an economically viable market for the treated product, and the need to address potential liability issues related to any residual contamination in the treated product. Further, implementability is dependent on the requirements of the state where the material is destined for beneficial use. Notwithstanding the above uncertainties, beneficial use may be an effective alternative to landfill disposal and thus, has been **retained for further evaluation during remedial design**.

5.2 TECHNOLOGY SCREENING SUMMARY

A summary of the screening of technologies and process options is presented in Table 5-1. Technologies that were retained are relatively common, effective, and implementable, and are incorporated into the development of remedial alternatives in Section 7. The selection of these technologies does not preclude consideration of other viable options, such as those that were identified for possible further evaluation during remedial design. It is anticipated that technology selection will be further informed by the ongoing remedial design in the lower 8 miles. As discussed above, the screening of technologies and process options draws on findings from bench-scale tests, pilot studies, and previous removal actions performed by EPA and its partner agencies, the CPG, and Tierra/Maxus/OCC. Emerging and innovative technologies not discussed in this FS may be evaluated during remedial design and adaptive management.

6 MODELING TO SUPPORT THE EVALUATION OF REMEDIAL ALTERNATIVES

6.1 OVERVIEW OF MODELING FRAMEWORK

As part of the LPRSA RI, a suite of coupled numerical models was developed to simulate the important processes affecting contaminant movement in the LPRSA. The suite comprises five models: a hydrodynamic model, a sediment transport model, an organic carbon model, a CFT model, and a bioaccumulation model.[43] Through parameterization and calibration, model results reasonably match measured data. Several of the components were originally developed by EPA, based in part on the Contaminant Assessment and Reduction Project of the New York/New Jersey Harbor Estuary Program model suite, and have been refined during the course of the LPRSA RI/FS. The models are subject to the requirements of the May 2007 Settlement Agreement (USEPA 2007) as well as the modeling work plan developed by EPA (HQI 2006a,b), and were approved by EPA for their application to the LPRSA RI/FS (USEPA 2019). A complete description of the model development and application is presented in the RI report (AQEA 2019).

The numerical models are applied to simulate the impact of the IR FS remedial alternatives on 2,3,7,8-TCDD and total PCBs (modeled as tetrachlorobiphenyls) sediment and water column concentrations for use in the detailed and comparative analysis of the alternatives. Projections were developed for each of the active alternatives (Appendix C). They include the construction period and extend 10 years following the completion of the largest alternative (i.e., the alternative with the longest construction period). The projected water column and sediment concentrations during and following construction are evaluated at specific locations and averaged over river reaches. Projections conducted to characterize uncertainty in the model results are used to bound the range of anticipated results. The model projections are presented in Section 8.

6.2 MODELING GUIDELINES

The LPRSA hydrodynamic, sediment transport, and CFT numerical model results provide some of the various metrics used to evaluate the alternatives in this FS. Although the current models are considered calibrated and sufficient for the purposes of preparing the IR FS, significant framework and parameter uncertainties associated with components of the complex LPRSA system limit the accuracy of the models' predictions, especially related to delineating areas subject to erosion and deposition, and to surface sediment recovery trends. EPA, NJDEP, and the CPG have identified and acknowledged that a high degree of caution should be applied

[43] The bioaccumulation model developed as part of the RI/FS modeling suite is currently undergoing final setup and calibration, and will subsequently undergo peer review prior to application. This model is not used in the IR FS.

when using those predictions to evaluate remedial alternatives (USEPA 2018e; NJDEP 2018; CPG 2018b).

Given the current uncertainty of the predictions, the evaluation and use of the model projections in this FS (and the proposed plan and ROD for the IR, if an IR is selected) is limited and strictly adheres to these guiding principles:

- Numerical modeling is only one of several FS metrics that is used to evaluate the IR alternatives.
- Absolute differences in model-projected post-IR concentrations and rates of recovery among alternatives are not considered; this is consistent with EPA OLEM's January 2017 Recommendation 7 (last paragraph).
- Model-projected post-IR concentrations are not compared to any concentration thresholds and do not consider the duration of time to reach any concentration thresholds.
- Multiple projections are conducted for the alternatives to characterize model uncertainty.
- Model-projected post-IR concentrations and rates of recovery are expressed as ranges. The ranges are established by the differences among the multiple projections conducted to assess uncertainty.
- Ranges of model-projected post-IR concentrations and rates of recovery are used to compare the active IR alternatives to each other and to the No Action alternative.
- When comparing alternatives, any overlap in the ranges of post-IR concentrations and rates of recovery are assessed to better understand the magnitude of model uncertainty relative to the modeled differences in alternatives. Overlap is not in itself presumed to render alternatives indistinguishable. Whether differences in model-projected post-IR concentrations and rates of recovery are meaningful or not is assessed in review of the completed model projections.

Projections are not used in the IR FS for decision-making in an absolute sense, including to judge the underlying setup of the modeling projections, to conclude the underlying appropriateness of the IR alternatives evaluated, or to extend the projections to future risk-based remediation decisions.

7 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section presents the rationale, assembly, and description of remedial alternatives for a source control IR in the upper 9-mile reach of the LPRSA.[44] The alternatives are assembled in a manner consistent with CERCLA guidance (USEPA 1988). The RAOs presented in Section 3 outline the remedial objectives of a source control IR.

Five remedial alternatives were developed for evaluation in the upper 9-mile IR FS:

- Alternative 1: No action
- Alternative 2: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 85 ng/kg and incorporating a total PCBs RAL of 1 mg/kg
- Alternative 3: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 75 ng/kg and incorporating a total PCBs RAL of 1 mg/kg
- Alternative 4: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 65 ng/kg and incorporating a total PCBs RAL of 1 mg/kg
- Alternative 5: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 125 ng/kg.

Alternatives 2 to 5 are framed around differing SWAC targets for 2,3,7,8-TCDD, so as to compare the potential relative benefits of achieving a lower post-IR SWAC in terms of source control and recovery with the higher cost, longer duration, and greater short-term project impacts associated with larger remedial areas and greater removal volumes. The target post-IR SWAC for total PCBs is controlled by the established total PCB background concentration of 0.46 mg/kg, and the available data suggest that a total PCBs RAL of 1 mg/kg will result in a SWAC at or below this concentration. Alternative 5, which does not achieve the RAOs, is included to compare a smaller remedy defined only by a 2,3,7,8-TCDD SWAC target of 125 ng/kg with the other alternatives. All of the alternatives incorporate previously conducted or currently planned LPRSA remedial actions: the completed Phase 1 removal action near the Lister Avenue site, the RM 10.9 time-critical removal action, and the planned lower 8-mile remedial action. Site-specific information, site-specific data, and, as necessary, assumptions regarding pending action were used to incorporate these remedial actions into the IR FS

[44] The analyses, tables, and figures presented in Sections 7 and 8 and Appendix C incorporate post-RM 10.9 removal conditions (see Section 3.1 of Appendix C for the description of model initial conditions). In contrast, the analyses, tables, and figures presented in Section 2 reflect pre-RM 10.9 removal conditions. One hundred conditional simulation maps, used in the desktop mapping analyses, provided values for remediation area, sediment volume, RALs, and SWAC at the time of remedy completion for each alternative. Initial SWACs for 2,3,7,8-TCDD and total PCBs, fluxes, water column concentrations, depositing concentrations, and year 10 post-IR concentrations were derived from the modeling analyses.

remedial alternatives. Detailed descriptions of the alternatives are presented below. The development of the remedial footprints, including derivation of a surface and subsurface RAL to address the RAOs, is discussed in Section 7.2 and Appendix B.

Alternative 1 is the No Action alternative as required by CERCLA guidance. Alternatives 2, 3, and 4 were developed to achieve the RAO 1 SWAC goals of 85 ng/kg for 2,3,7,8-TCDD and 0.46 mg/kg for total PCBs and to provide a comparison of relative performance and benefit among alternatives that meet and exceed the target SWACs. Alternative 5 does not meet the RAOs, but, as discussed above, was developed for comparative evaluation to characterize performance of a smaller remedial action that may not achieve the same degree of source control as the other active alternatives. The active alternatives are evaluated and compared with each other and with the No Action alternative.

The development and evaluation of all five remedial alternatives, including model projections of their implementation and the long-term system response to remediation, incorporate the Phase 1 removal action performed in 2011–2012, the RM 10.9 time-critical removal action performed in 2013–2014, and the planned lower 8-mile remedial action.

Consistent with the anticipated role of adaptive management in remediation of the upper 9 miles of the LPRSA, all active remedial alternatives assume that the design, implementation, and long-term performance monitoring of a source control IR for the upper 9 miles would incorporate adaptive management principles. The adaptive management program would establish performance criteria and metrics to be applied to assess the long-term recovery beyond completion of an IR, triggers for diagnostic assessment in the event recovery does not meet the performance criteria, and potential response actions. An initial Adaptive Management Implementation Approach for the upper 9 miles is summarized in Section 1.4 and presented as Appendix D to this IR FS.

7.1 COMMON ENGINEERING ASSUMPTIONS AND CONSIDERATIONS

Common engineering elements and technical and administrative considerations applicable to the implementation of the four active remedial alternatives are summarized below. The initial selection of process options was based on the screening presented in Section 5, lessons learned from the RM 10.9 and the Phase 1 removal actions, and professional judgment. These elements were selected for the IR FS evaluation and are not necessarily those that would be selected during remedial design and implementation. Other remedial technology process options that have been retained for future consideration, as discussed in Section 5, may be considered during the remedial design. The final remedial design would be reviewed and approved by EPA.

7.1.1 Sediment Removal

Sediment would be removed to the depths necessary to accommodate sediment caps. Dredge depths are anticipated to be 2 to 3 ft, including allowable overdredging. For the purpose of the cost estimate, the IR FS assumes a removal depth of 2.5 ft (2-ft nominal dredge depth plus 0.5-ft overdredge).

Mechanical dredging with a conventional barge-mounted clamshell dredge and/or environmental bucket is assumed as the primary process option for the IR FS. Other equipment (e.g., barge-mounted precision excavator) will be evaluated during remedial design and implementation.

Land-based removal is assumed for the area above RM 13.9 to accommodate fixed, low-clearance bridge constraints that preclude barge and tug operations upstream of RM 13.9.

For this IR FS, it is assumed that dredging will be feasible within the entirety of the remedial footprint. All possible effort to perform active dredging, where feasible, throughout the remedial footprint will be undertaken. If, during remedial design, portions of the remedial footprint where significant constraints (e.g., utility crossings, bridge abutments, and critical shoreline structures) limit or preclude dredging and capping, ENR and *in situ* sediment treatment will be considered as alternate technologies for those areas.

Dredging methods will be further evaluated during remedial design to support development of construction performance requirements. RM 10.9 cap performance monitoring data will continue to be assessed to inform the dredging approach for an IR (and possibly a final remedy). The remediation contractor will identify means and methods to satisfy the performance requirements in the design documents, including selection of appropriate dredging/capping equipment.

As mentioned in Section 5.1.7, dredging without capping (or "dredge-to-clean") is retained for further evaluation in the remedial design. Dredging without capping is a remedial approach that includes removal of sediment to a surface that does not require capping to isolate remaining sediment. It can provide a high degree of long-term effectiveness and permanence as an alternative to dredging and capping in areas where it is technically feasible and does not result in increased remediation costs, as discussed below. During the IR design, PDI data would be assessed using the following principles to determine if dredging without capping is appropriate:

- Would be considered within the dredge footprint developed to meet the source control IR RAOs.
- Would be considered where native material (the identifier of "clean") is observed in the sediment cores collected in the PDI.

- Would be considered where the costs associated with deeper dredging to reach native sediment and backfill placement are at or below the cost of dredging to the nominal dredge depth, capping, and long-term cap monitoring[45]
- Would be evaluated where the depth to native material over an area of 0.25 or more contiguous acres is sufficiently shallow to provide a cost break-even or cost neutral result, as determined using the depth to native material of at least two adjacent PDI cores[46]
- Would be implemented in a manner compatible with engineering, constructability, sediment stability, and safety constraints that may affect short-term effectiveness and implementation.

The following steps would be performed to determine the areas where dredging without capping would be employed:

1. Before the PDI, a mutually agreed upon cost model would be developed and used to compare the cost of (a) dredging to the nominal dredge depth, with capping and long-term cap monitoring to (b) dredging to reach native sediment and backfill placement (which includes evaluating depths deeper than the nominal dredge depth). Unit costs from the IR FS would be refined, as possible and necessary, and used in the cost comparison model. So that the costs are sufficiently developed for this exercise, the cost drivers associated with dredging and capping would be reviewed and possibly refined prior to using them in the cost model. Also, the backup and/or references used to establish the unit costs in the cost model would be identified. It is expected that this model would identify the depth(s) at which the costs of the two dredging options would be the same. These depths would be used to refine the termination depth of the PDI borings in each area of the river, if greater than the nominal PDI boring depth (see Section 7.1.6); it is anticipated that cores would need to extend 1-ft beyond the depth at which the costs of the two dredging options are equal.
2. The PDI sampling would be conducted to the depths established, with the depth at which native material is encountered in each boring (up to the termination depth for the area in the river the boring is located) to be recorded. The depth of native material would be determined from visual observation of the sediment cores.

[45] During design, EPA and the Performing Parties would determine the cost break-even relationship of dredging to native material and placing a residual sand layer instead of dredging to a nominal depth for cap placement. This cost-benefit analysis will be applied on a decision management unit (or smaller) scale where proposed cap types, possible additional dredging depths, and dredging conditions are relatively consistent over the area and can be assessed effectively.
[46] It is anticipated that sediment sampling would be performed on a grid with roughly 80-ft spacing between sample locations.

3. Preliminary dredge management units (DMUs) where two or more adjacent borings intersect native material would be identified.
4. As part of the remedial design program, the cost comparison model would be updated using cost data from remediation contractors, disposal facilities, etc. and location-specific conditions that may vary among the DMUs.

The updated model would be used to determine the cost comparison for each preliminary DMU. Dredging without capping would be selected for those DMUs where dredging without capping would cost no more than dredging and capping.

7.1.2 Dredged Material Management

For this IR FS, it is assumed that dredged sediment would be transported via barge to a nearby commercial facility for processing. For example, there are three Clean Earth sediment processing facilities within a 3-mile radius of the mouth of the Passaic River (Kearney, Koppers, and Claremont). Facility capacity and accessibility evaluations will be required during the design to identify which location(s) are available and accessible. Alternative sediment processing options, including the possible use of the planned lower 8-mile processing facility or another facility, may be evaluated during remedial design.

Following dewatering of the sediment on the barge and stabilization at the processing facility, sediment would be transported via railcar and/or truck for offsite disposal. For this IR FS, it is assumed the sediment would be transported via rail from the sediment processing facility. Precautions would be taken during transport to prevent the release of contamination; specific actions will be identified during design and implementation.

The NCP establishes an expectation that EPA will use treatment to address the principal threats posed by a site wherever practicable (NCP §300.430(a)(1)(iii)(A)). Principal threats are source materials that contain hazardous substances, pollutants, or contaminants acting as a reservoir of contaminants that can migrate to groundwater, surface water, or air, or act as a direct source of exposure. USEPA (1991d) defines principal threat waste as follows: "Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. They include liquids and other highly mobile materials (e.g., solvents) or materials having high concentrations of toxic compounds." Classification of principal threat waste is made on a site-specific basis to support waste and disposal management decisions. In the ROD for the lower 8.3 miles, EPA identified the most highly contaminated sediment as principal threat waste in this reach, but nonetheless determined that deeper sediment can be reliably contained and that additional treatment of all the sediment in the lower 8.3 miles is not practicable or cost-effective, given the high volume of sediment, the number of COCs that would need to be addressed, and the lack of applicable treatment technologies (USEPA 2016a).

For the upper 9 miles, EPA will identify sediment, if any, that would be classified as principal threat waste, and the need and practicability of additional treatment as a component of dredged material management would be evaluated.

Nonhazardous dredged material may be accepted for direct disposal in a RCRA Subtitle D facility, contingent on the facility's permit, available space, and facility-specific acceptance criteria for material impacted by chlorinated dioxins and furans. Hazardous dredged material would require disposal in a RCRA Subtitle C facility following treatment, if necessary, to meet all regulatory requirements. In previous removal actions, EPA has determined that sediment from the LPR does not contain RCRA-listed hazardous waste (USEPA 2008c; CH2M Hill 2019). However, during the Phase I removal action near the Lister Avenue site, sediment was encountered that had to be managed as characteristic hazardous waste, and an analysis of the Phase I removal data in the lower 8.3 mile ROD responsiveness summary estimated 5 percent of the sediment by volume exceeded RCRA waste characterization criteria. If PCB concentrations indicate TSCA-regulated sediment is encountered during dredging, then TSCA regulations will be followed (currently available data from the upper 9 miles do not suggest TSCA-regulated sediment is likely to be encountered). Waste characterization sampling conducted preliminarily during the PDI, with final testing taking place prior to disposal and in accordance with receiving facility requirements, would be used to identify dredged material requiring management as a RCRA characteristic waste. For the purposes of this IR FS, it is assumed that all dredged material will be sent for direct disposal in a Subtitle C facility, given the uncertainty regarding acceptance of material from the LPR at a Subtitle D facility.

7.1.3 Mitigation of Dredging Residuals

Appropriate construction equipment and BMPs would be used during implementation to minimize the generation and transport of residuals. Residual contaminated sediment remaining after remediation can be categorized as undisturbed or generated (Patmont et al. 2018). Undisturbed residuals are contaminated sediment remaining at the post-dredging sediment surface that has been uncovered by dredging but not removed (USACE 2008b). Primary causes of undisturbed residuals include dredging limitations such as hardpan or structures, incomplete characterization or inappropriate dredge design elevation, inaccuracies in meeting target dredging elevations, and development of dredging plans that do not target complete removal due to engineering limitations or other factors (USACE 2008b). Generated residuals are contaminated sediment that is resuspended during dredging and subsequently redeposited.

Mitigation of dredge residuals would be managed in response to real-time construction performance monitoring data. The specific array of BMPs or engineering controls implemented during the IR would vary according to location-specific conditions. Potential BMPs to evaluate during design for dredging residuals and water quality management include the following:

- Implement real-time construction performance monitoring, including chemical measurements, bathymetry surveys, and continuous turbidity measurements upstream and downstream of construction areas.
- Remove debris prior to dredging.
- Minimize residuals generation by dredge control and design, such as carefully controlling depth, location, and cutting action to maximize sediment capture and minimize sloughing and bottom impacts. Optimize dredge bucket fill efficiency to minimize both free-water capture and overfill fallback.
- Control speed of bucket through the water column to minimize loss of adhered sediment.
- Allow the sediment-filled bucket to drain before fully emerging above the water surface.
- Contain drippage during the overwater swing of a filled bucket (e.g., by placing an empty barge or apron under the swing path during offloading).
- Use an environmental or sealed bucket in most instances except where conditions require other equipment.
- Start dredging in upslope areas and move downslope to minimize sloughing.
- Plan multiple dredge cuts, limit initial cut depths to avoid sloughing of the cut bank, and plan initial cut(s) to limit resuspension.
- Use floating and/or absorbent booms to capture floating debris or sheens.
- Use conventional construction stormwater BMPs to control and reduce the silt burden in runoff from barges or rehandling areas.
- Deploy silt curtains or other suitable containment features (subject to suitable site conditions).
- Limit or suspend dredging during high flows following significant storm events.
- Sequence dredging to remove areas with the most elevated sediment contaminant concentration first to minimize recontamination.

Placement of sand outside of the dredge and cap areas, known as residual management cover (RMC), is among the BMPs that may be used to mitigate the impacts of generated dredge residuals that resettle to the sediment bed. For this IR FS, it is assumed that a nominal 6-in. RMC would be placed outside the dredge and cap footprint, over an area approximately equal to 20 percent of the dredge footprint, based on engineering judgment. The actual area will be determined through construction quality assurance sampling during remedial construction. RMC may also be placed within a dredge area if capping is delayed.

Capping would be performed in multiple lifts to minimize resuspension. It is assumed cap material would be placed as soon as practicable following confirmation of dredge prisms to contain residuals and underlying contaminated sediment.

7.1.4 Capping

For the purposes of the IR FS, it is assumed that cap material will be transported via barge and placed with a mechanical bucket. Upstream of RM 13.9, land-based cap material placement is assumed for the IR FS to accommodate fixed, low-clearance bridge constraints that preclude barge and tug operations upstream of RM 13.9.

Consistent with the RM 10.9 design (CH2M Hill 2013), a 1-ft isolation layer was evaluated over a 100-year time frame to determine the cap composition that would be effective at limiting migration of underlying sediment contaminants (Appendix F). An evaluation of potential armor size and thickness was performed with flows associated with a 100-year return period, consistent with EPA guidance (USEPA 2005). For the purposes of the feasibility-level cap stability analysis, armor is assumed to be placed throughout the cap footprint, to a thickness of 1 ft (Appendix F). Armor thickness would be refined in the remedial design. In shoal areas, habitat reconstruction material similar to existing substrate is assumed to be placed throughout the shoals, as the top 1 ft of the cap. Further consideration and refinement of the ecological and recreational function of the cap would be considered during the remedial design, at which time its composition would be determined. Cap types and thickness would vary depending on location and armoring requirements. Bathymetric data, geomorphic evaluations, and hydrodynamic and sediment transport model results would be used to determine erosional areas that would be proposed for armored cap placement. Additional design considerations, such as the addition of *in situ* reactive amendments would be established during remedial design. It is anticipated that one important cap design consideration would be the potential for an engineered cap to exacerbate erosion in adjacent uncapped areas. Placement of caps on slopes greater than 3:1 would require additional geotechnical analyses and design to evaluate feasibility. For the IR FS, it is assumed that cap thicknesses would vary from approximately 2 ft (in low-energy areas) to approximately 2.5 ft (in areas subject to greater erosion potential). A 2.5 ft cap is assumed throughout the remedial footprint for the purpose of the IR FS cost estimate.

Further evaluation of capping methods would be performed during remedial design to develop appropriate performance requirements for cap placement. RM 10.9 physical and chemical cap performance monitoring data will continue to be assessed to inform the capping approach for an IR (and possibly a final remedy). Data and lessons learned from cap construction and cap construction monitoring at the RM 10.9 removal action area would also be relied on to inform the capping approach. The remediation contractor would select appropriate methods and equipment to satisfy the performance requirements in the design.

7.1.5 Monitored Natural Recovery

Accelerated natural recovery is expected in the unremediated areas of the upper 9 miles of the LPR as a result of a source control IR. Recovery assessment monitoring following the implementation of an IR would evaluate recovery in both remediated and unremediated areas.

7.1.6 Monitoring

Monitoring consists of baseline, construction, operation and maintenance (O&M), and long-term monitoring. In the IR FS, long-term monitoring is assumed to occur for 30 years spanning two phases. These include a system response and recovery assessment phase following IR completion and a subsequent phase of long-term monitoring following selection of a final remedy and issuance of the final ROD. The Current Conditions sampling of biota and surface water (under way in 2019 to 2021) and the PDI of sediment will establish pre-remediation baseline conditions for comparison purposes and provide data to support the remedial design. Monitoring assumptions for the IR FS include:

An IR completion assessment process would be performed to verify that RAO 1 has been achieved. The assessment would consider construction monitoring conducted during remediation to evaluate compliance with the performance requirements specified by the remedial design (i.e., water quality monitoring, bathymetric surveys, discharge monitoring, inspection surveys, sediment sampling to evaluate the residuals management measures being employed[47]) and post-remedy confirmatory sediment sampling. These monitoring activities, together with a multi-stage PDI and a robust design process and footprint delineation, comprise the multiple lines of evidence that will be evaluated to verify attainment of RAO 1. The remedy completion assessment process is described in Appendix H. Anticipated monitoring activities, as assumed for this IR FS, are summarized below.

- The PDI is anticipated to include:

[47] Limited sediment sampling would be performed after the completion of the dredging season, targeting newly deposited sediment on top of capped areas and/or areas that have received RMC, for the objective of evaluating the efficacy of and potential improvements to dredging BMPs. The utility of the sediment sampling would be evaluated and this sampling may be discontinued after the first season or a subsequent season if (a) sampling of newly deposited materials proves impracticable, (b) the concentrations of newly deposited sediment are consistent with or lower than near-field water column concentrations measured during active dredging, or (c) the variability and complexity of the system limits the ability to ascertain the cause of any elevated concentrations in newly deposited sediment and consequently limits the ability to revise BMPs any further than what is concluded using the water column data. If sediment sampling is discontinued because water column concentrations are predictive of residual concentrations (item b, above) but significant and sustained non-compliance with water column performance standards directly related to dredging occurs after the discontinuation, additional sediment sampling may be triggered to evaluate BMP efficacy so long as earlier sampling found it to be practical and useful for BMP applications.

  - Sediment sampling on a spatially dense grid (approximately 2,000 locations) from RM 8.3 to Dundee Dam to evaluate surface and subsurface conditions (the spatial density of sampling may be less in areas of coarse sediment)
  - A second round of sediment sampling to refine the delineation of the remedial footprint, better constrain data variability, and minimize the potential for targeting errors in the IR footprint, as needed
  - Sediment sampling is anticipated to include coring to a nominal depth of 4 ft. Anticipated coring intervals are 0 to 0.5 ft, 0.5 to 1.5 ft, 1.5 to 2.5 ft, and 2.5 to 4 ft. Core depths may be extended and/or core intervals may be refined during the PDI to ensure achievement of the data use objectives:
    - Characterization of the surface sediment interval
    - Characterization of subsurface sediment for (a) waste characterization of sediment above the dredge depth and (b) characterization of sediment below the dredge depth for cap design
    - Characterization of sediment that may be removed following the cost break-even evaluation for dredging without capping (see Section 7.1.1)
  - Bathymetry/LiDAR survey
  - Debris identification survey
  - Geotechnical evaluations
  - Supporting surveys (e.g., habitat, cultural, fish spawning).
- Construction monitoring is anticipated to include confirmatory bathymetric surveys to verify dredge depths and cap placement thicknesses, water quality monitoring, and sediment sampling to evaluate the efficacy of residual management measures. Cap construction verification is also anticipated to include sediment coring to verify cap layer(s) thickness(es) and composition as prescribed by the IR design, and to evaluate potential mixing of cap layers with underlying sediment during cap placement. This information would be used to directly confirm achievement of cap layer IR design specifications. It would also help inform any future cap monitoring efforts focused on assessing the cap's performance in chemically isolating any underlying contaminants. Performance metrics would be established during the remedial design to ensure achievement of dredging and capping extents and other performance standards. Data and lessons learned from cap construction, cap construction monitoring, and physical and chemical cap performance monitoring at the RM 10.9 removal action area would be relied on to inform the IR cap construction monitoring approach.
- Post-IR confirmation sampling would include sufficient samples to provide a statistically unbiased estimate of the post-IR SWACs, and is anticipated to include not

less than 400 and not more than 800 sediment sample locations at which three closely spaced samples will be collected and composited.

- O&M monitoring of cap areas would be conducted following construction to ensure long-term effectiveness. Bathymetry surveys and chemical monitoring would be performed to assess the continued stability and chemical isolation performance of the cap and any potential need for maintenance to ensure continued performance (e.g., replacement of eroded cap material and/or armor stone). Chemical monitoring to evaluate contaminant isolation may consist of sediment coring and sample analysis and/or the use of passive samplers. Data and lessons learned from cap performance monitoring at the RM 10.9 removal action area would be relied on to inform the IR cap O&M monitoring approach. Cap O&M monitoring would continue until 30 years after the end of construction.[48]
- Long-term monitoring to evaluate effectiveness of the IR would start with recovery assessment monitoring upon completion of construction and will continue for a period of 30 years.[49] The long-term monitoring activities are described in Appendix D.

7.1.7 Institutional Controls

Each of the remedial alternatives is assumed to include a combination of institutional controls. Institutional controls would likely be needed both during and following completion of the IR, until RGs are achieved. RGs are yet to be determined, and would be documented in a final ROD. Possible institutional controls include the following:

- Governmental controls (i.e., monitoring and notification of waterway users)
  - Commercial fishing ban
  - Prohibitions on anchorage within the areas that are capped
  - Prohibitions on grounding of small vessels on the shoreline
  - Restrictions of vessel draft, horsepower, and speed
  - Restrictions on dredging, piling placement or removal, or other construction activities that may disturb sediment
- Proprietary controls (i.e., easements and restrictive covenants related to cap)
- Informational devices (i.e., deed notices, fish consumption advisories, and signage).

[48] Issuance of a final ROD would replace the cap monitoring and maintenance requirements of the IR.
[49] Issuance of a final ROD would replace the recovery assessment monitoring requirements of the IR with a second phase of long-term monitoring.

7.1.8 Habitat Considerations

The impact on and recovery of ecological habitat areas is an important aspect of remedial alternatives that involve construction in intertidal mudflats and wetland areas. These areas are home to communities of fish, birds, invertebrate species, and vegetation (Windward and AECOM 2009).

There would be a short-term impact associated with active remedial alternatives during construction and following completion of construction, as disturbed benthic and near-shore habitat areas recover. Remedial design would include management of these areas to approximately restore the habitat that supports ecological value equal to current conditions and avoid net loss of habitat, in accordance with the dredge and fill requirements of the Clean Water Act, described in Table 4-2.

7.1.9 Construction Constraints

The selection of representative equipment and production rates to be used for the purposes of this IR FS have been based, in part, on the consideration of various construction constraints, including:

- Bridges with low or limited crossing access, especially above RM 13.9
- Navigational constraints of shallow water or strong currents
- Migratory fish window limitations
- Critical structure protection.

Design assumptions, including size of equipment, production rates, anticipated fish windows and winter shutdown periods, are presented in Appendix A. Further evaluation of construction constraints (e.g., utility corridors, construction setbacks) and potential strategies to mitigate the associated impact on construction (e.g., dredge productivity) would be completed during remedial design.

7.2 BASIS FOR ESTABLISHING REMEDIAL ALTERNATIVE FOOTPRINTS, CONSTRUCTION QUANTITIES, AND DURATIONS

Each of the active remedial alternatives, introduced above in Section 7.1, is designed to address sediment sources that are inhibiting natural recovery. The alternatives differ primarily on the 2,3,7,8-TCDD target SWAC to be achieved by an IR. Establishing estimates of areas of active remediation (i.e., remedial "footprints") to attain the target SWAC for each alternative depends on estimates of surficial sediment concentrations in the upper 9 miles of the LPRSA. Similarly, estimating the areas that may represent potential subsurface sources needing active remediation to comply with RAO 2 depends on estimates of subsurface sediment concentrations.

This section presents the mapping performed to develop these estimates and define the footprint for active remediation under each alternative. In addition, the assumptions used in the IR FS to estimate remedial alternative construction quantities and remedial action construction durations are specified.

7.2.1 Remedial Alternative Footprints

A geostatistical interpolation procedure termed as conditional simulation was used to generate 100 equally probable maps of surface (0–0.5 ft) and subsurface (0.5–1.5 ft) concentration distributions of the LPR sediment bed (see Appendix B). The RI report for the LPRSA (AQEA 2019; RI Appendix J) describes the procedures used to estimate the spatial distributions of 2,3,7,8-TCDD and total PCBs in surface and subsurface sediment based on the RI sediment sampling data. Interpolated surface and subsurface sediment contamination concentration maps are needed to depict patterns of contemporary contamination, support the development of IR FS remedial alternatives, and set initial conditions for the modeling evaluation of these alternatives.

In summary, concentration fields of 2,3,7,8-TCDD and total PCBs over the river bottom (i.e., concentration maps) were estimated for surface sediment (0–0.5 ft) and the underlying subsurface sediment (0.5–1.5 ft) using the RI data and geostatistical interpolation (AQEA 2019, RI Appendix J). For surface sediment, conditional simulation was used to generate 100 equally probable random realizations of the concentration field. Conditional simulation is based on kriging, which is an interpolation method that produces gridded estimates of the parameter of interest and the uncertainty of those estimates (i.e., the prediction error), given the observed data and a variogram function that characterizes spatial correlation. The 100 concentration maps all reproduce the mean and variance of the observed data and the covariance as defined by the variogram. The measured concentrations at sample locations are also honored, although some deviation may arise from the resolution of the grid and the assumed variance at very small separation distances. Corresponding maps of subsurface concentrations in the 0.5–1.5 ft depth interval were generated by pairing the conditional simulation results at each interpolation grid cell with a data resampling technique that enforces the observed relationship between surface and subsurface concentrations (as described in RI Appendix J, the method draws a subsurface concentration from a pool of sediment core data selected based on the mapped concentration in the overlying surface sediment).

For each of the maps, remedial footprints were developed for each of the four IR FS active remedial alternatives using the following sequence of steps:

1. Sample Conditional Simulation Map: The maps were sampled at the vertices of an approximately 80-ft on-center triangular grid overlaid on the maps and adjusted, where needed, to provide adequate coverage of each geomorphic group used in the mapping (silt areas were separated from non-silt areas, and channels and shoals were separated in

non-silt areas; see AQEA 2019, RI Appendix J). Thiessen polygons were drawn around each sample point, adjusting for geomorphic boundaries, to assign it an area of influence. These polygons are termed "decision units" and the sample points are termed "centerpoints."

2. Target Areas for RAO 1:
   a. Initial selection of targeted decision unit polygons: All decision unit polygons with centerpoints that fell between RM 8.3 and RM 15 were targeted if the centerpoint total PCB concentration was 1 mg/kg or greater.
   b. Consecutive selection of target decision unit polygons: Additional polygons were targeted in decreasing order of centerpoint 2,3,7,8-TCDD concentration (i.e., hill-topping) until the RM 8.3 to RM 15 post-remedy SWAC met the IR FS alternative SWAC goal. In computing the SWAC, targeted polygons were assigned a post-remediation 2,3,7,8-TCDD concentration of 10 ng/kg to reflect recontamination that might occur during remediation, and untargeted polygons were assigned the true mean concentration of the underlying conditional simulation map (not the centerpoint concentrations drawn in Step 1 above). The lowest targeted polygon centerpoint concentration defines the 2,3,7,8-TCDD RAL for a given remedial alternative (the derived RAL is specific to the conditional simulation map being used for delineation).
3. Target Areas for RAO 2:
   a. Selection of a subsurface (0.5–1.5 ft) RAL for RAO 2: A higher subsurface RAL was used in areas that exhibited erosion because the probability of further erosion in these areas is less than 100 percent. The subsurface RAL was set to 2 times the surface RAL (established for RAO 1), which is analogous to assuming that there is a 50 percent chance of enough additional erosion to expose the subsurface (0.5–1.5 ft) sediment. Bathymetry differences indicate that areas that exhibited 0.5 ft or more of erosion between 2008 and 2010 had approximately a 25 percent probability of eroding another 0.5 ft or more during a time period that included Hurricane Irene. This supports using a 4x multiplier for the RAO 2 subsurface RAL, but a 2x multiplier was adopted to be conservative. Section 4.2.1 and Attachment 1 of Appendix B provide additional details. Although the assessment of erosion probability is used to support a 2x multiplier for subsurface RALs, the selection of the 2x multiplier is a site management decision, based on lines of evidence, reached by EPA in consultation with NJDEP.
   b. Evaluation of untargeted decision unit polygons: Untargeted decision unit polygons within erosional areas were evaluated for remediation based on subsurface total PCB and 2,3,7,8-TCDD concentrations in the 0.5–1.5 ft interval. Erosional areas were defined using bathymetric survey data where available (mainly in the channel, using the 2007 to 2012 bathymetric change categories developed in RI Section 4) and model

predictions for remaining areas between RM 8.3 and RM 15 (specifically, areas experiencing maximum predicted erosion of 6 in. or more over the 2007 to 2012 period,[50] which included Hurricane Irene). For decision unit polygons with centerpoint subsurface total PCB concentration greater than or equal to 2 mg/kg or centerpoint subsurface 2,3,7,8-TCDD concentration greater than or equal to twice the RAL (determined in Step 2b above), the portion of the decision unit within erosional areas was added to the footprint.[51]

The above procedure was applied to a base map (Conditional Simulation 37 [CS 37], selected as a central tendency map across several characteristics) to develop the IR alternatives.[52] The footprints for the four active remedial alternatives considered in the IR FS are presented in Section 7.3. Additional details of the approach are provided in Appendix B. It is noted that the footprint delineations used in model projections differ somewhat from those described above. The main difference is that the identification of erosional areas for the RAO 2 targeting was based only on the model-predicted long-term erosion rate (see Appendix B).

Discussion of the uncertainty associated with the selection of CS 37 as the base map to estimate important components of each active remedial alternative (including RALs, remedial footprint acreages, construction quantities, and construction durations) is presented in Section 8.2 and Appendix C. A sensitivity evaluation of the assumptions underlying the RAO 2 RAL multiplier selection is presented in Appendix B, considering the potential impact to 2,3,7,8-TCDD SWACs of erosion in the RAO 2 footprint area exposing subsurface concentrations up to twice the surface RAL (i.e., exposing sediment that would be targeted if the RAO 2 subsurface RAL were instead set equal to the surface RAL). The analysis in Section 4.2.2 of Appendix B indicates that the target SWAC would likely still be met even under highly conservative assumptions of erosion within the RAO 2 footprint area, thereby further supporting the use of twice the surface RAL as the trigger for remediation for subsurface sediment in erosional areas.

7.2.2 Remedial Alternative Construction Quantities

Estimated quantities for sediment to be dredged under each remedial alternative are based on the remedial footprint multiplied by the assumed dredge depth of 2.5 ft, which includes a provision for a 0.5-ft overdredge allowance (Appendix A). Similarly, cap volumes are based on the estimated areal footprint of active remediation and the cap thickness, which is assumed to range from approximately 2 ft (in low-energy areas) to approximately 2.5 ft (in areas subject to

[50] Erosion predicted to occur during the 2007 to 2012 period may include sediment deposited prior to 2007.
[51] The Thiessen polygon-based delineation assigns the centerpoint concentrations to the entire polygon. This means that the portion of the polygon that is erosional is assumed to have the centerpoint concentrations and the decision of whether to include it in the delineation is based on those concentrations.
[52] The development of the mapping procedure and the selection of CS 37 was performed collaboratively with EPA.

greater erosion potential). For cost estimation purposes, it is assumed that a 2.5 ft cap is placed, which includes an assumed 0.5 ft overplacement of cap materials (Appendix A).

7.2.3 Remedial Alternative Construction Durations

Estimated construction durations for each alternative are based on the assumed footprints, construction quantities, and production rates specified in Appendix A.

7.3 THE REMEDIAL ALTERNATIVES

This section describes the remedial alternatives. Figures 7-1 through 7-5 present the remedial footprints for Alternatives 1 through 5.[53] Active remedial footprints for Alternatives 2 through 5 were developed using the sediment bed mapping approach and targeting protocol described in Section 7.2, and are based specifically on the selection of CS 37 as the basis for developing estimates of remedial footprints, construction quantities, and construction durations for the IR FS. These footprints, quantities, and durations are developed for the purposes of the IR FS. The footprint for the ultimately selected alternative will be developed based on the results of the PDI that will be conducted prior to the remedial design.

Table 7-1 presents a summary of the estimated areas, volumes, and durations associated with each remedial alternative.

7.3.1 Alternative 1: No Action

Alternative 1 consists of no remedial action in the upper 9 miles of the LPRSA (Figure 7-1). As with the active alternatives, Alternative 1 incorporates the Phase 1 removal action, the RM 10.9 removal action, and the planned lower 8-mile remedial action. This alternative does not include provisions for additional institutional controls beyond the current controls implemented through other regulatory programs (e.g., NJDEP fish and shellfish consumption advisories). Alternative 1 does not include monitoring and reporting performed in support of the other past and planned removal and remedial actions in the LPRSA.

7.3.2 Alternative 2: 2,3,7,8-TCDD SWAC of 85 ng/kg, Total PCBs RAL of 1 mg/kg

Alternative 2 includes dredging and capping between RM 8.3 and RM 15 in the remedial footprint delineated following the procedures described in Section 7.2 and shown on Figure 7-2. Alternative 2 would target source material with high concentrations of 2,3,7,8-TCDD and total PCBs, achieving a post-IR target 2,3,7,8-TCDD SWAC of 85 ng/kg and implementing a total

[53] These figures display the USACE river mile system. USACE and EPA remedial investigation river miles on the site differ by approximately 0.3 mile due to the specification of the zero river mile location.

PCBs RAL of 1 mg/kg for surface sediment (0–0.5 ft). The delineation of the remedial footprint to address RAO 1 results in a surface RAL for 2,3,7,8-TCDD of 260 ng/kg (discussed in Section 7.2 and Appendix B). Alternative 2 also includes additional dredging and capping in areas with erosional potential and high subsurface sediment concentrations (0.5–1.5 ft) to address RAO 2. Areas with high subsurface concentrations were delineated by applying subsurface RALs that are twice the surface RALs (520 ng/kg for 2,3,7,8-TCDD and 2 mg/kg for total PCBs). The inclusion of areas to address RAO 2 results in a 2,3,7,8-TCDD SWAC of 80 ng/kg and a total PCB SWAC of 0.29 mg/kg. Table 7-2 provides a summary of the SWACs and RALs for all alternatives.

7.3.2.1 Alternative 2 Elements

Alternative 2 includes all of the common engineering assumptions and considerations detailed in Section 7.1. Dredged materials would be processed at one or more nearby commercial processing facilities. Following completion of an IR, recovery assessment monitoring and adaptive management would be implemented to assess the progress of Alternative 2 towards PRGs, to be developed during IR design, and ultimately, RGs that will be derived and documented in a final ROD.

7.3.2.2 Estimated Quantities and Construction Time Frame

Based on the estimated technical specifications for the remedial alternatives shown in Table 7-1, Alternative 2 would target approximately 363,000 cy of contaminated sediment from a total area of approximately 90 acres. For the IR FS, it is assumed that an approximate equivalent quantity of clean fill materials would be imported for cap, armoring, backfill, and RMC placement.

The estimated construction time frame is approximately 4.3 years, considering the anticipated fish window and assumed production rates. A detailed summary of the conceptual design assumptions for Alternative 2 is provided in Appendix A.

7.3.3 Alternative 3: 2,3,7,8-TCDD SWAC of 75 ng/kg, Total PCBs RAL of 1 mg/kg

Alternative 3 includes dredging and capping between RM 8.3 and RM 15 in the remedial footprint delineated following the procedures described in Section 7.2 and shown on Figure 7-3. Alternative 3 would target source material with high concentrations of 2,3,7,8-TCDD and total PCBs, achieving a post-IR 2,3,7,8-TCDD SWAC of 75 ng/kg and implementing a total PCBs RAL of 1 mg/kg for surface sediment (0–0.5 ft). The delineation of the remedial footprint to address RAO 1 results in a surface RAL for 2,3,7,8-TCDD of 205 ng/kg (discussed in Section 7.2 and Appendix B). Alternative 3 also includes additional dredging and capping in areas with erosional potential and high subsurface sediment concentrations (0.5–1.5 ft) to address RAO 2. Areas with high subsurface concentrations were delineated by applying subsurface RALs that

are twice the surface RALs (410 ng/kg for 2,3,7,8-TCDD and 2 mg/kg for total PCBs). The inclusion of areas to address RAO 2 results in a 2,3,7,8-TCDD SWAC of 70 ng/kg and a total PCB SWAC of 0.27 mg/kg. Table 7-2 provides a summary of the SWACs and RALs for all alternatives. Figure 7-6 shows the additional area targeted under Alternative 3 compared with Alternative 2, which includes an additional 6 acres of footprint from RM 8.3 to RM 14, located mostly below RM 12.

7.3.3.1 Alternative 3 Elements

Alternative 3 includes all of the common engineering assumptions and considerations detailed in Section 7.1. Dredged materials would be processed at one or more nearby commercial processing facilities. Following completion of an IR, recovery assessment monitoring and adaptive management would be implemented to assess the progress of Alternative 3 towards PRGs, to be developed during IR design, and ultimately, RGs that will be derived and documented in a final ROD.

7.3.3.2 Estimated Quantities and Construction Time Frame

Based on the estimated technical specifications for the remedial alternatives shown in Table 7-1, Alternative 3 would target approximately 387,000 cy of contaminated sediment from a total area of approximately 96 acres. For the IR FS, it is assumed that an approximate equivalent quantity of clean fill materials would be imported for cap, armoring, backfill, and RMC placement.

The estimated construction time frame is approximately 4.6 years, considering the anticipated fish window and assumed production rates. A detailed summary of the conceptual design assumptions for Alternative 3 is provided in Appendix A.

7.3.4 Alternative 4: 2,3,7,8-TCDD SWAC of 65 ng/kg, Total PCBs RAL of 1 mg/kg

Alternative 4 includes dredging and capping between RM 8.3 and RM 15 in the remedial footprint delineated following the procedures described in Section 7.2 and shown on Figure 7-4. Alternative 4 would target source material with high concentrations of 2,3,7,8-TCDD and total PCBs, achieving a post-IR 2,3,7,8-TCDD SWAC of 65 ng/kg and implementing a total PCBs RAL of 1 mg/kg for surface sediment (0–0.5 ft). The delineation of the remedial footprint to address RAO 1 results in a surface RAL for 2,3,7,8-TCDD of 164 ng/kg (discussed in Section 7.2 and Appendix B). Alternative 4 also includes additional dredging and capping in areas with erosional potential and high subsurface sediment concentrations (0.5–1.5 ft) to address RAO 2. Areas with high subsurface concentrations were delineated by applying subsurface RALs that are twice the surface RALs (328 ng/kg for 2,3,7,8-TCDD and 2 mg/kg for total PCBs). The inclusion of areas to address RAO 2 results in a 2,3,7,8-TCDD SWAC of 60 ng/kg and a total PCB SWAC of 0.24 mg/kg. Table 7-2 provides a summary of the SWACs and RALs for all

alternatives. Figure 7-7 shows the additional area targeted under Alternative 4 compared with Alternative 3, which includes an additional 8 acres of footprint from RM 8.3 to RM 15, located mostly below RM 13.

7.3.4.1 Alternative 4 Elements

Alternative 4 includes all of the common engineering assumptions and considerations detailed in Section 7.1. Dredged materials would be processed at one or more nearby commercial processing facilities. Following completion of an IR, recovery assessment monitoring and adaptive management would be implemented to assess the progress of Alternative 4 towards PRGs, to be developed during IR design, and ultimately, RGs that will be derived and documented in a final ROD.

7.3.4.2 Estimated Quantities and Construction Time Frame

Based on the estimated technical specifications for the remedial alternatives shown in Table 7-1, Alternative 4 would target approximately 419,000 cy of contaminated sediment from a total area of approximately 104 acres. For the IR FS, it is assumed that an approximate equivalent quantity of clean fill materials would be imported for cap, armoring, backfill, and RMC placement.

The estimated construction time frame is approximately 4.9 years, considering the anticipated fish window and assumed production rates. A detailed summary of the conceptual design assumptions for Alternative 4 is provided in Appendix A.

7.3.5 Alternative 5: 2,3,7,8-TCDD SWAC of 125 ng/kg

Alternative 5 includes dredging and capping between RM 8.3 and RM 15 in the remedial footprint delineated following the procedures described in Section 7.2 and shown on Figure 7-5. Alternative 5 would target source material with high concentrations of 2,3,7,8-TCDD, achieving a post-interim remedy 2,3,7,8-TCDD SWAC of 125 ng/kg. The delineation of the remedial footprint results in a surface (0–0.5 ft) RAL for 2,3,7,8-TCDD of 346 ng/kg (discussed in Section 7.2 and Appendix B). For this alternative, while PCBs would be removed from the remedial footprint, total PCBs were not specifically targeted so as to derive a smaller footprint for comparison to other alternatives; therefore, no PCBs RAL was applied. Alternative 5 also includes additional dredging and capping in areas with erosional potential and high subsurface sediment concentrations (0.5–1.5 ft) to address RAO 2. Areas with high subsurface concentrations were delineated by applying a subsurface RAL that is twice the surface RAL (692 ng/kg for 2,3,7,8-TCDD). Inclusion of these areas in the remedial footprint results in a 2,3,7,8-TCDD SWAC of 121 ng/kg and a total PCBs SWAC of 0.49 mg/kg. Table 7-2 provides a summary of the SWACs and RALs for all alternatives. Figure 7-8 shows the decrease in area

targeted under Alternative 5 compared with Alternative 4, which is a decrease of 42 acres from RM 8.3 to RM 15.

7.3.5.1 Alternative 5 Elements

Alternative 5 includes all of the common engineering assumptions and considerations detailed in Section 7.1. Dredged materials would be processed at one or more nearby commercial processing facilities. Following completion of an IR, recovery assessment monitoring and adaptive management would be implemented to assess the progress of Alternative 5 towards PRGs, to be developed during IR design, and ultimately, RGs that will be derived and documented in a final ROD.

7.3.5.2 Estimated Quantities and Construction Time Frame

Based on the estimated technical specifications for the remedial alternatives shown in Table 7-1, Alternative 5 would target approximately 250,000 cy of contaminated sediment from a total area of approximately 62 acres. For the IR FS, it is assumed that an approximate equivalent quantity of clean fill materials would be imported for cap, armoring, backfill, and RMC placement.

The estimated construction time frame is approximately 3.2 years, considering the anticipated fish window and assumed production rates. A detailed summary of the conceptual design assumptions for Alternative 5 is provided in Appendix A.

8 DETAILED EVALUATION AND COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

In this section, a detailed evaluation of the five remedial alternatives is conducted to assess the performance of each alternative with respect to the NCP criteria, in accordance with EPA guidance (USEPA 1988) and using the specific metrics developed for the evaluation of the IR alternatives (Section 8.1.4, Table 8-1). A comparative analysis is performed to evaluate and rank the relative performance of the alternatives (Sections 8.4). The comparative analysis also includes an evaluation of green and sustainable remediation (GSR) metrics for the active alternatives to compare the environmental, social, and economic impacts that would accompany the implementation of an IR (Section 8.4.3). A summary of the comparative analysis is presented in Section 8.5.[54]

8.1 NCP EVALUATION CRITERIA

USEPA (1988) and the NCP (40 CFR § 300.430(e)(9)(iii)) require consideration of nine evaluation criteria to address the CERCLA regulatory requirements for remedy selection. These consist of two threshold criteria, five primary balancing criteria, and two modifying criteria, as defined below.

8.1.1 Threshold Criteria

Under CERCLA, each IR alternative must meet two threshold criteria to be eligible for selection as the preferred alternative.

1. Overall protection of human health and the environment: Addresses whether the alternative achieves and maintains adequate protection of human health and the environment in relation to the scope and goals of a remedial action, drawing on several other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.
2. Compliance with ARARs: Addresses whether the alternative complies with ARARs relevant to the alternative or if a waiver is justified; and whether the alternative is consistent with other criteria, advisories, and guidance that are to be considered.

[54] The analyses, tables, and figures presented in Section 8 and Appendix C incorporate post-RM 10.9 removal conditions (see Section 3.1 of Appendix C for the description of model initial conditions). In contrast, the analyses, tables, and figures presented in Section 2 reflect pre-RM 10.9 removal conditions. One hundred conditional simulation maps, used in the desktop mapping analyses, provided values for remediation area, volume, RALs, and SWAC at the time of remedy completion for each alternative. Initial SWACs for 2,3,7,8-TCDD and PCBs, fluxes, water column concentrations, depositing concentrations, and year 10 post-IR concentrations were derived from the modeling analyses.

The source control IR FS alternatives are assessed relative to the threshold criteria. Given that the purpose of an IR is to address higher contaminant concentrations in sediment that act as sources inhibiting recovery, and not to establish or attain specific risk-protective RGs, and that the purpose of this IR FS is to develop and compare IR alternatives, PRGs are not established in the IR FS. PRGs would be developed following an IR ROD, in parallel with an IR remedial design, and would be used to assess the future recovery of the system and to inform a final ROD including final RGs. EPA's final determination of the ability of remedial actions to meet RGs for protection of human health and the environment and to comply with ARARs will be made in the final ROD for the LPRSA.

8.1.2 Primary Balancing Criteria

The IR FS evaluates source control alternatives against the following five primary balancing criteria established in the NCP:

1. Long-term effectiveness and permanence: Addresses the magnitude of residual risk following remedy implementation and the adequacy and reliability of controls.
2. Reduction of toxicity, mobility, or volume through treatment: Addresses (i) the treatment or recycling processes that the alternatives employ; (ii) the amount of contaminants that will be destroyed, treated, or recycled; (iii) the degree of expected reduction in toxicity, mobility, or volume; (iv) the degree to which the treatment is irreversible; (v) the type and quantity of residuals that will remain; and (vi) the degree to which treatment reduces the inherent hazards posed by principal threats at the site.
3. Short-term effectiveness: Addresses the effects of the alternative during construction/ implementation; effectiveness and reliability of protective or mitigative measures; ability to protect the community and workers during construction; and the length of time until RAOs are achieved.
4. Implementability: Addresses the ease or difficulty of implementing an alternative given its technical feasibility, administrative feasibility, and availability of services and materials to construct and operate the remedy.
5. Cost: Evaluates the estimated capital and O&M costs associated with the alternative. Cost estimates are prepared in accordance with the provisions of RI/FS guidance (USEPA 1988) and the cost estimating guide (USEPA 2000a). Under the NCP, cost-effectiveness of the remedial alternatives must be considered, weighing the overall effectiveness of each alternative (based on its long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; and short-term effectiveness) against its cost to ensure that a selected remedy will be cost-effective. The NCP considers a remedy to be cost-effective *"if its costs are proportional to its overall effectiveness (40 CFR §300.430(f)(1)(ii)(D))."*

The primary balancing criteria are used, in combination, to weigh effectiveness, implementability, and cost trade-offs among remedial alternatives that meet the threshold criteria. They represent the primary technical criteria upon which the detailed alternative evaluation is based.

8.1.3 Modifying Criteria

The two modifying criteria are state acceptance and community acceptance, which are considered by EPA during remedy selection and ROD preparation.

1. State acceptance: Considers state positions and/or concerns related to the preferred alternative and other alternatives; and the state's comments on ARARs or the proposed use of waivers.
2. Community acceptance: Considers support, opposition, or concerns expressed by interested members of the community regarding the preferred alternative or other alternatives.

If EPA selects a preferred alternative on the basis of this IR FS, modifying criteria would be evaluated after a proposed plan is released for regulatory and public review.

8.1.4 IR FS Metrics

The performance metrics used in the IR FS to evaluate the remedial alternatives are primarily based on the estimated technical specifications of the alternatives (Section 7.2), calculated post-IR SWACs, and model projections to characterize the sediment and water column contaminant concentrations during and after remedy implementation.

For each of the NCP criteria, a set of metrics was developed to evaluate and compare the five IR FS remedial alternatives relative to the threshold and balancing criteria (Table 8-1). Evaluation metrics include both qualitative and quantitative metrics to ensure a thorough evaluation against the NCP criteria. Metrics that are based on quantitative model projections (Table 8-2) are presented as ranges to show the sensitivity of the projections to model input parameters, as discussed in Sections 8.2.4 and 8.2.5. Details of the development and application of quantitative models for the IR FS are discussed in Appendix C.

8.1.4.1 Threshold Criteria

The two threshold criteria described above address overall protection of human health and the environment and compliance with ARARs, as defined under the NCP (40 CFR § 300.430). Alternatives are evaluated against the following specific IR FS metrics for these criteria:

1. Overall Protection of Human Health and the Environment

   a. Ability to achieve the source control goals established in the IR RAOs
   b. Ability to progress toward overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations[55]
2. Compliance with ARARs
   a. Ability to achieve ARARs
   b. Potential need for ARAR waivers.

The threshold criteria are evaluated with qualitative metrics to support the detailed and comparative analysis of the alternatives and to integrate the relevant factors contributing to each criterion, based on the specifications of each remedial alternative:

- Meets criterion—the alternative is determined to be capable of meeting the threshold criterion
- Does not meet criterion—the alternative is determined to be incapable of meeting the threshold criterion.

8.1.4.2 Primary Balancing Criteria

Metrics for the five balancing criteria represent the primary basis for the detailed and comparative analysis of alternatives in the IR FS.

Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of a remedial alternative addresses the degree of risk reduction it achieves and the adequacy and reliability of its environmental controls. To evaluate long-term effectiveness and permanence, the following three IR metrics were identified: source control and recovery potential; cap stability; and monitoring, maintenance, and institutional controls.

Source Control and Recovery Potential

The conceptual model for recovery in the upper 9 miles indicates that legacy contaminated sediment is a source of high contaminant concentrations to the water column, and recovery is limited by net erosion and cyclic erosion and deposition of higher concentration sediment that redeposits onto the surface sediment layer, resulting in low recovery in these areas (Section 2.6). Addressing these sources can be expected to result in reduction of contaminant concentrations in the water column and recovery of sediment outside of the remedial footprint. The data

[55] Given that the IR alternatives are not compared against risk-based goals, the threshold to achieve overall protection of human health and the environment is characterized as (a) attainment of the IR RAOs for source control and (b) the ability to progress toward overall protection by promoting the accelerated recovery of the water column and sediment following implementation of an IR.

collected and evaluated during the RI suggest that legacy sediment sources can be controlled by addressing sediment with high concentrations of 2,3,7,8-TCDD (on the order of 200 to 400 ng/kg and higher) and total PCBs (greater than approximately 1 mg/kg), as discussed in Section 2.6. Potential sources can be controlled by addressing subsurface sediment with high concentrations of 2,3,7,8-TCDD and total PCBs in areas of potential erosion.

The control of sources following implementation of an IR is expected to be evident in the sediment with overall lower concentrations of 2,3,7,8-TCDD and total PCBs, a shift in the frequency distribution of concentrations to lower values, and a significant reduction in SWAC and accelerated SWAC recovery compared with the No Action alternative. Evidence of source control in the water column is expected to include a reduction in 2,3,7,8-TCDD and total PCB contaminant erosion flux from the sediment bed (i.e., a reduction in the source strength), which will lead to a reduction in water column concentrations and concentrations on depositing fine sediment. These reductions will result in reduced contaminant load moving out of the upper 9 miles. Following removal of source sediment, SWACs will be significantly reduced.

A source control IR would promote recovery in the water column and accelerate recovery of sediment outside of the remedial footprint, consistent with the conceptual model of system recovery. Recovery of sediment and the water column would be expected to result in recovery of fish and crab tissues.

The IR FS metrics used to evaluate the alternatives against the source control and recovery potential metrics (Table 8-1) are described below.

Efficacy of RALs based on the CSM

The CSM has identified that removal of sediment that is impeding recovery will result in accelerated recovery of sediment, water column, and tissue concentrations; this sediment is characterized by evaluation of water column particulate concentrations, and defined as having 2,3,7,8-TCDD concentrations in the range of 200 to 400 ng/kg or higher and total PCB concentrations greater than 1 mg/kg (Section 2.6). The RALs for each alternative (Table 8-3) are compared to this range of water column particulate concentrations to evaluate whether the alternative is anticipated to effectively address sources of 2,3,7,8-TCDD and total PCBs in surface and subsurface sediment and achieve the source control goals of an IR established under RAO 1 and RAO 2.

Areas, masses, and volumes of source removal

The areas, masses, and volumes of source sediment removal for each alternative are evaluated and compared quantitatively and discussed qualitatively to evaluate the potential for each alternative to achieve source control by removing sediment with the highest concentrations (Table 7-1).

Distribution of post-IR concentrations relative to pre-IR concentrations

The spatial distributions, using the CS 37 base map, of post-IR 2,3,7,8-TCDD and total PCB surface sediment concentrations are compared to pre-IR concentrations to evaluate the effectiveness of each alternative to address high concentrations and achieve source control. The distributions of surface sediment concentrations are evaluated as follows:

- CS 37 mapped surface concentrations of 2,3,7,8-TCDD and total PCBs pre- and post-IR implementation (Figures 8-1 and 8-2)
- Frequency distribution of CS 37 mapped surface concentrations of 2,3,7,8-TCDD and total PCBs pre-and post-IR implementation (Figures 8-3 and 8-4).[56]

Model projections

Model projections are evaluated to compare the active alternatives with each other and with the No Action alternative to assess their relative performance during and after active remediation. Model projections were performed for an 18-year period, where years 0 to 8 are referred to as the pre-IR completion period, and include the IR construction from approximately years 3 to 8, and years 9 to 18 are referred to as the post-IR period. The model hydrograph is presented in Figure 8-5 to support interpretation of the variations in model projections that could be caused by variations in the hydrograph; specifically high flow events that can lead to short-term increases in projected concentrations. The evaluation of model projections is performed in accordance with the model guidelines described previously (Section 6.2). Because all the alternatives (including Alternative 1, the No Action alternative) incorporate the planned lower 8-mile remedial action, the evaluation allows for direct comparison of the relative performance of the active alternatives in the context of both the upper 9 miles and the entire LPRSA. Model projections are presented as ranges to show their sensitivity to model input parameters, and the ranges are used in the evaluation to characterize the uncertainty in the model predictions. Section 8.2 and Appendix C discuss model uncertainty and the development of ranges.

Presentation of the model projections used to support evaluation of source control and recovery potential include a series of figures, each with the following three panels:

a. Time series of annual results for the 10-year post-IR period (model years 9 to 18), where results shown at each year represent the year end average.

b. Bar chart of summary of results at the end of the 10-year post-IR period (end of model year 18; SWACs and cumulative loads) or averaged over the 10-year post-IR period

[56] The post-IR concentrations shown on Figures 8-1 through 8-4 are based on CS 37 and reflect substitution of replacement values of 10 ng/kg for 2,3,7,8-TCDD and 0 mg/kg for total PCBs within the active remedial footprints for each alternative. Post-IR concentrations higher than the RALs for each remedial alternative reflect targeting errors, as discussed in Appendix B.

(water column concentrations, gross and net erosion flux, and concentrations on depositing fine sediment).

c. Pie chart showing the fraction of the total reduction at the end of the 10-year post-IR period (end of model year 18) or averaged over the 10-year post-IR period achieved incrementally by the largest alternative (Alternative 4) relative to No Action (Alternative 1), moving from the smallest footprint (Alternative 5) to the largest footprint (Alternative 4). This chart is discussed in the comparative analysis (Section 8.4).

Model projections used to support achievement of source control and recovery potential are described below:

Model projections of average sediment concentrations and recovery half-life

Model projections of 2,3,7,8-TCDD and total PCBs SWACs are evaluated over the 10-year post-IR period (model years 9 to 18) and compared with the No Action alternative and among alternatives to evaluate the effect of a source control IR on SWACs immediately following an IR and as they continue to recover. In addition, model projections are evaluated to compare the active alternatives with each other and with the No Action alternative to assess potential for the alternatives to result in recovery of sediment and the water column. Model projections of SWACs are presented as follows:

- Projected 2,3,7,8-TCDD SWAC in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-6)
- Projected total PCBs SWAC in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-7)
- Projected 2,3,7,8-TCDD SWAC in RM 0 to RM 8.3 for Alternatives 1 to 5 (Figure 8-8)
- Projected total PCBs SWAC in RM 0 to RM 8.3 for Alternatives 1 to 5 (Figure 8-9)
- Projected 2,3,7,8-TCDD SWAC in RM 0 to RM 15 for Alternatives 1 to 5 (Figure 8-10)
- Projected total PCBs SWAC in RM 0 to RM 15 for Alternatives 1 to 5 (Figure 8-11).

The estimated recovery half-life of the projected sediment SWACs, or the time to reduce the initial post-IR SWAC by 50 percent,[57] is a measure of the potential for ongoing recovery following implementation of an IR. A comparison with the No Action alternative shows the acceleration of recovery with implementation of an IR. A comparison among alternatives shows the relative time over which recovery is projected to occur. Recovery half-life for 2,3,7,8-TCDD and total PCBs in RM 8.3 to RM 15 for Alternatives 1 to 5 is presented in Figure 8-12.

[57] The recovery half-life is calculated relative to the alternative-specific SWAC at the end of model year 8; the SWAC achieved after one half-life is therefore much lower for Alternative 2 than for Alternative 1. See Appendix C for a discussion of the half-life calculation.

Model projections of average water column concentrations

Model projections of 2,3,7,8-TCDD and total PCBs water column concentrations are evaluated over the 10-year post-IR period (model years 9 to 18) and compared with the No Action alternative to evaluate the effect of removal of source sediment on water column concentrations and compared among the alternatives to evaluate the degree of additional reduction with larger sediment removal volumes. A reduction in water column concentrations is anticipated following removal of source sediment. Model projections of water column concentrations are presented as follows:

- Projected 2,3,7,8-TCDD water column concentration in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-13)
- Projected total PCBs water column concentration in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-14).

Model projections of average and cumulative water column loads

Model projections of average and cumulative water column loads are evaluated over the 10-year post-IR period (model years 9 to 18) and compared with the No Action alternative to evaluate the effect of removal of source sediment on water column loads and compared among the alternatives to evaluate the degree of additional reduction with larger sediment removal volumes. Water column loads, or the transport of contaminants on water column particulates upstream and downstream in the LPR, are anticipated to decline when water column concentrations decline. Water column loads are evaluated at the upstream end of the IR reach (RM 15), the downstream end of the IR reach (RM 8.3), and at the downstream end of the LPR (RM 0). Cumulative water column loads are a sum of the annual water column loads, starting at the first year post-IR (model year 9). Model projections of water column loads are presented as follows:

- Projected 2,3,7,8-TCDD average water column load at RM 15 for Alternatives 1 to 5 (Figure 8-15)
- Projected 2,3,7,8-TCDD average water column load at RM 8.3 for Alternatives 1 to 5 (Figure 8-16)
- Projected 2,3,7,8-TCDD average water column load at RM 0 for Alternatives 1 to 5 (Figure 8-17)
- Projected 2,3,7,8-TCDD cumulative water column load at RM 15, RM 8.3, and RM 0 for Alternatives 1 to 5 (Figure 8-18)
- Projected total PCBs average water column load at RM 15 for Alternatives 1 to 5 (Figure 8-19)
- Projected total PCBs average water column load at RM 8.3 for Alternatives 1 to 5 (Figure 8-20)

- Projected total PCBs average water column load at RM 0 for Alternatives 1 to 5 (Figure 8-21)
- Projected total PCBs cumulative water column load at RM 15, RM 8.3, and RM 0 for Alternatives 1 to 5 (Figure 8-22).

Model projections of average gross and net contaminant erosional flux

The gross erosional flux is the rate at which contaminants are eroded into the water column. It is a measure of the strength of a sediment source to introduce contaminant mass to the water column, including mass that eroded from within the IR area and mass that is introduced to the IR area from upstream or downstream areas. The net erosional flux is the difference between gross erosional flux and the flux of depositing sediment contaminants. It is a measure of the net export of contaminant eroded from the sediment bed in the IR reach (RM 8.3 to RM 15) to other regions. A similar reduction in gross and net erosional flux indicates that the removal of sediment under an alternative removes the dominant contaminant sources. If the reduction in net flux is greater than the reduction in gross flux, it indicates that addressing source areas reduces erosional flux, but due to ongoing sources upstream of the LPRSA, depositional flux is not reduced to the same extent, which causes the gross erosion from sediment in the RM 8.3 to RM 15 reach to continue at levels that are closer to the No Action alternative. Model projections of contaminant erosional flux are compared with the No Action alternative to characterize the reduction in sediment source strength following implementation of an IR, and among the alternatives to characterize the additional reduction of sediment source strength with additional sediment removal. Model projections of contaminant erosional flux are presented as follows:

- Projected 2,3,7,8-TCDD gross erosional flux in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-23)
- Projected total PCBs gross erosional flux in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-24)
- Projected 2,3,7,8-TCDD net erosional flux in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-25)
- Projected total PCBs net erosional flux in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-26).

Model projections of contaminant concentrations on depositing fine sediment

Contaminant concentrations on depositing fine sediment are the contaminant concentrations that are eroded from the sediment bed and subsequently redeposit in depositional areas of the sediment bed. These concentrations will decline following a reduction of the contaminant erosional flux, or the strength of the sediment source. The reduction in contaminant concentrations on depositing fine sediment will result in recovery of sediment in depositional areas outside of the remedial footprint. Model projections of contaminant concentrations on depositing fine sediment are compared with the No Action alternative to characterize the

concentration reduction following implementation of an IR, and among the alternatives to characterize the additional concentration reduction with additional sediment removal. Model projections of contaminant concentrations on depositing fine sediment are presented as follows:

- Projected 2,3,7,8-TCDD concentrations on depositing fine sediment in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-27)
- Projected total PCBs concentrations on depositing fine sediment in RM 8.3 to RM 15 for Alternatives 1 to 5 (Figure 8-28).

Cap Stability

The alternatives are assessed for the degree to which a cap could be designed, implemented, and maintained to adequately and reliably isolate contaminants remaining in the sediment bed for long-term effectiveness and permanence of an IR. The primary evaluation metric is cap modeling of the projected time before breakthrough of the cap. The cap modeling evaluation is presented in Appendix F.

Monitoring, Maintenance, and Institutional Controls

A qualitative discussion is presented to evaluate and compare the degree to which each of the alternatives requires long-term monitoring and maintenance and institutional controls to ensure long-term effectiveness and permanence.

Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion addresses the degree to which an alternative uses treatment to reduce the toxicity, mobility, or volume of contaminants.

The main elements of the active source control remedial alternatives are removal, processing, and disposal of contaminated sediment and capping. For each active alternative, a discussion of the *ex situ* treatment during sediment processing is presented. The addition of an organic carbon amendment to the capping material is also discussed as an *in situ* treatment technology. The degree of achievement of this criterion is determined for each alternative based on the volume of removal, contaminant mass removed, and cap area covered.

Short-Term Effectiveness

The criteria developed to evaluate short-term effectiveness are time to achieve RAOs, worker risks, community impact, resuspension, and potential for contaminant transport during construction. Sustainability is also considered as discussed in Section 8.4.3. The specific evaluation metrics are described below.

Time to Achieve RAOs

Achievement of the RAOs will be determined at the end of the IR completion assessment process (see Section 7.1.6 and Appendix H for a description of the IR completion assessment process). Evaluation metrics are achievement or non-achievement of the RAOs and time to achieve RAOs, which is based on the estimated construction duration plus the time needed for EPA to reach a determination on IR completion. It is anticipated that the IR completion assessment process will take approximately 3 years following the active construction period, which includes implementation of sediment sampling, analysis of results, potential additional sediment sampling, and the decision-making process following completion of data collection (see Appendix H).

Worker Risks and Community Impacts

Evaluation of worker risks during construction consists of a qualitative assessment of potential physical hazards and risks to workers including exposure to contaminants and operational hazards such as light, noise, and air emissions. Evaluation of community impacts during construction consists of a qualitative assessment of the potential for significant quality-of-life and economic impacts to residents, commuters, and businesses in the project area resulting from increased construction activity and road, rail, and marine traffic during implementation of the remedial alternatives. The degree of these impacts is a function of the estimated duration, construction quantities, and anticipated construction activities for each of the alternatives.

Resuspension

The short-term impact of potential resuspension during construction is evaluated by comparing model projections of water column concentrations during construction among the active alternatives and with the No Action alternative. A discussion of residual management to reduce or minimize impacts due to potential resuspension of sediment during dredging is presented in Sections 7.1.2 and 8.2.2. Model projections are presented as ranges to show their sensitivity to model input parameters (Section 8.2 and Appendix C discuss model uncertainty).

Model projections used to evaluate resuspension are as follows:

- Projected annual water column concentrations of 2,3,7,8-TCDD and total PCBs in RM 8.3 to RM 15 during the pre- IR completion period (model year 1 to 8[58]) (Figure 8-29).

[58] Model results are shown as year-end averages or totals (e.g., model results plotted at year 1 are an average over the first year of the projection period).

Transport

The short-term impact of potential contaminant transport outside of the active remedial area (downstream of RM 8.3 and/or upstream of RM 15) is evaluated by comparing model projections of water column fluxes during construction among the active alternatives and with the No Action alternative. Model projections are presented as ranges to show their sensitivity to model input parameters (Section 8.2 and Appendix C discuss model uncertainty).

Model projections used to evaluate transport are as follows:

- Projected average annual water column downstream loads of 2,3,7,8-TCDD at RM 15, RM 8.3, and RM 0 during the pre-IR completion period (model initiation to year 8[59]) (Figure 8-30)
- Projected cumulative water column downstream loads of 2,3,7,8-TCDD at RM 15, RM 8.3, and RM 0 during the pre-IR completion period (model initiation to year 8[59]) (Figure 8-31)
- Projected average annual water column downstream loads of total PCBs at RM 15, RM 8.3, and RM 0 during the pre-IR completion period (model initiation to year 8[59]) (Figure 8-32)
- Projected cumulative water column downstream loads of total PCBs at RM 15, RM 8.3, and RM 0 during the pre-IR completion period (model initiation to year 8[59]) (Figure 8-33).

Implementability

A qualitative evaluation of remedy implementability includes the construction challenges, potential challenges due to availability of materials, technical feasibility of and need for BMPs and monitoring, consideration of future use, and potential administrative matters and challenges. Lessons learned from early actions on the LPR are discussed, specifically feasibility impacts due to numerous utility crossings, shoreline structures, bridge pilings, and transport of equipment and materials up and down the LPR.

Administrative feasibility includes coordination requirements with property owners, local governments, and other agencies (e.g., the steps required to establish long-term or future coordination among agencies, and the ease or difficulty of complying with ARARs, including obtaining permit equivalents for onsite activities and permits for offsite activities).

Many municipalities and counties along the LPR have published master plans that anticipate increased future use along the river including the expansion and improvement of parks and

[59] Model results are shown as year-end averages or totals (e.g., model results plotted at year 1 are an average over the first year of the projection period).

open space along the river, which, if implemented, will lead to greater access to the river and improved ecological habitat in the future (Heyer 2008; Phillips Preiss Grygiel 2012; Nishuane Group 2011; Fernandez 2013; Passaic River Coalition 2015). Other goals for LPR waterfront property include light industry, research incubation, and mixed use commercial, residential, and entertainment (Belleville Township Planning Board and CME Associates 2019; Heyer 2008).

The anticipated overlap in construction of the upper 9-mile and lower 8-mile remedial actions and the potential to coordinate to facilitate implementability is considered.

Cost

Feasibility-level cost estimates are developed and compared for each alternative (Appendix G). Consistent with EPA guidance (USEPA 2000a), these estimates are considered accurate within a range of +50 percent to –30 percent in relation to actual implementation costs of a selected remedy. The cost estimates include capital costs and annual and periodic monitoring and maintenance costs for 30 years post-remedy. The design assumptions (Appendix A) for each alternative are used to develop the costs. A 25 percent contingency is assumed for each alternative. Costs are presented as present value estimates, using the EPA-preferred discount rate of 7 percent (Table 8-4).

A cost sensitivity analysis was performed for varying discount rates and contingency assumptions (Table 8-5). The contingency was varied from 25 to 35 percent. The EPA-default discount rate of 7 percent was compared to 1.5 percent, a reasonable expected discount rate for a 30-year project based on information published by the U.S. Office of Management and Budget (OMB) (OMB 2018). For comparison purposes, the undiscounted cost (i.e., discount rate of 0) was also included in the sensitivity analysis for each alternative. The sensitivity of the cost estimate to the selection of mechanical versus hydraulic dredging and to disposal at Subtitle C versus Subtitle D landfills was evaluated for Alternative 3 (Section 8.4.2.5 and Appendix G).

8.1.4.3 Modifying Criteria

Modifying criteria are state acceptance and community acceptance, which may be used to modify aspects of the preferred alternative when preparing the ROD. Modifying criteria are evaluated after the FS is released for regulatory and public review, following analysis of public comment on EPA's proposed plan. State and community acceptance are evaluated by EPA through coordination and outreach with stakeholders throughout the remedy selection process. EPA is obligated under the NCP to consider state and community concerns in its evaluation of state and community acceptance in the ROD, following the public comment period on EPA's proposed plan.

8.2 UNCERTAINTIES

Data collection and evaluations were performed during the RI and during preparation of the IR FS; however, there are significant uncertainties in several key elements of these evaluations. Rather than extend the RI and delay remedial actions, and consistent with EPA directives on management of contaminated sediment sites in the presence of uncertainty (USEPA 2017), these uncertainties are identified and their potential impacts on the development and evaluation of alternatives are acknowledged. For the purposes of the IR FS, assumptions regarding these elements were developed to proceed with the FS. The Current Conditions sampling program, data that would be collected during the PDI, and the evaluations that would be performed during the remedial design would further the understanding of the river and reduce uncertainty.

8.2.1 Remedial Footprints and Volume Estimates

The delineation of remedial footprints is an uncertainty in the IR FS and a key sensitivity factor driving the cost and duration of remedial actions. The final dredge and cap prisms for the selected remedy would be determined during remedial design based on the results of PDI sampling. Dredge volume uncertainties are commonly addressed in an FS by incorporating contingencies to allow for refinement of the dredge prism during remedial design and to account for typical dredging inaccuracies (e.g., allowable overdredge).

The remedial footprints for the IR FS alternatives are based on conditional simulation maps, as discussed in Section 7.2 and Appendix B. This approach uses geostatistical interpolation to map the sediment bed due to the relatively limited sediment bed concentration data and the associated uncertainty in the contaminant distributions. The statistical interpolation was applied to generate 100 equally probable maps (or conditional simulations) of sediment bed concentration. As described in Section 7.2, a single map, the CS 37 base map, was selected for development of the alternatives as it represents the central tendency of the 100 maps.[60] To characterize the effect of map selection on remedial footprint, the footprints were delineated for all 100 maps to develop a range of estimated remedial footprint areas and removal volumes for the four active alternatives (Table 8-3). As discussed in Section 7.2, hill-topping was used to delineate footprints, sequentially adding area to the remedial footprint in order of decreasing concentrations until the target SWAC for each alternative was achieved. Once remedial footprints were delineated to achieve the target SWAC, an RAL for surface sediment was determined based on the lowest concentration within the delineated footprint. The range of RALs for the active alternatives for the 100 maps is shown in Table 8-3. For the IR FS, the target SWAC was achieved by hill-topping over the RM 8.3 to RM 15 reach; during the remedial design, a modification to the delineation approach may be evaluated that could establish

[60] CS 37 was selected for development of alternatives in this IR FS in collaboration with EPA.

different RALs in different geomorphic areas (e.g., shoals and channels), resulting in SWACs that achieve the RAOs, but with a different remedial footprint reflecting variable RALs.

The IR final footprints would be delineated during remedial design, following collection of the PDI sediment data and bathymetric data. These data, which would include closely spaced sample locations, would significantly reduce the current level of uncertainty in the map of sediment bed concentrations and the footprint delineations. Appendix H provides additional discussion on the anticipated process for delineating the final remedial footprints during the remedial design.

8.2.2 Contaminant Resuspension, Release, and Recontamination during Remediation

Dredging and capping during remedial construction can result in resuspension of contaminated sediment into the water column, release of contaminants from bedded or resuspended sediment, and recontamination of previously remediated areas and/or adjacent unremediated areas. Residual contaminated sediment remaining after remediation can be categorized as undisturbed or generated residuals (Patmont et al. 2018). Undisturbed residuals are contaminated sediment within the remedial footprint that are not removed during dredging due to dredging limitations such as hard pan or structures. Generated residuals are contaminated sediment that is resuspended during dredging and subsequently redeposited. The uncertainty associated with estimation of resuspension/release and anticipated levels of residual contamination introduces uncertainty in model projections of remedy effectiveness (USACE 2008b).

Construction monitoring results from prior dredging activities on the LPR indicate that, with the implementation of appropriate BMPs, residual resuspension and release during dredging can be managed to minimize the impact on remediation and recovery. During the removal action at RM 10.9, no water column action level exceedances for turbidity were observed during construction monitoring[61] (CH2M Hill 2019). Water quality monitoring performed during the LPR Dredging Pilot Study (NJDOT/USACE 2012) indicated that contaminant concentrations were similar upstream and downstream of the dredging operations, and that observed water column concentrations in the near-field (400 ft from the dredge) and far-field (1,000 ft from the dredge) could not be attributed to dredge releases. Calculated sediment release into the water column in the near-field was approximately 1 percent of the dredge volume, with higher release rates observed intermittently, during dredging startup, due to storms and when BMPs were not optimal. Similar results were found during construction monitoring at sites in the Lower

[61] Modeling performed for the lower 8-mile FFS suggested that there could be little to no suspended solids releases, but potentially significant contaminant releases during dredging (LBG 2014a).

Duwamish Waterway, where water quality exceedances were not observed during dredging due to appropriate implementation of BMPs (AECOM 2015c; Integral 2012).

The potential effects of resuspension, release, and dredge residuals on recontamination were considered in two ways in the IR FS. For the calculation of remedial footprints and SWACs (Section 8.2.1), post-remediation values of 10 ng/kg for 2,3,7,8-TCDD and 0 mg/kg for total PCBs were assumed in remediated areas that address RAO 1 and RAO 2. In the CFT model, simulations were performed assuming that 1 and 3 percent of the contaminant mass in the dredged material was released into the water column. These assumed values, for the purposes of the IR FS evaluation, were established during the IR FS technical discussions among EPA, NJDEP, and CPG (Appendix K). During the remedial design, resuspension, release, and residual generation would be assessed, and BMPs would be implemented during construction to minimize their impact on the implementation of an IR (Section 7.1.3). The model projections are sensitive to the specified release rates, as demonstrated by the results presented in Appendix C.

8.2.3 Subsurface Action Levels

Delineation of remedial action areas to address RAO 2 includes selection of an RAL for subsurface sediment in areas potentially subject to erosion but not remediated to address RAO 1. The relatively sparse information on subsurface sediment contaminant concentrations and limited (spatially and temporally) bathymetric data limit the ability to definitively identify potential erosional areas and to characterize the potential impact of these areas on SWACs. For the IR FS, a subsurface RAL of twice the surface RAL was selected as a site management decision, supported by the assessment of erosion probability and the sensitivity analysis of SWAC impact resulting from theoretical erosion as presented in Appendix B, to delineate remedial action areas for RAO 2.[62] To characterize the effect of the selection of the subsurface RAL on remedial footprints, subsurface RALs were calculated for active alternatives in the 100 maps for factors of 1 and 2 of the surface RAL (Table 8-6).

Sediment and bathymetry data collection would be performed as part of the PDI and would support a refined characterization of subsurface sediment contaminant concentrations and erosional areas during the remedial design. The subsurface RAL would be reevaluated during the PDI, and the final subsurface RAL would be selected based on an evaluation of exposure likelihood and erosion potential. The maximum value of the factor of the surface RAL to be used for establishing the subsurface RAL, as a final site management decision, will be 2.

[62] The multiplier for the subsurface RAL was selected in collaboration with EPA and NJDEP.

8.2.4 Model Uncertainty

Although considered calibrated, the current HST and CFT[63] models have framework and parameter uncertainties that limit the accuracy of their projections. Of note are uncertainties and inaccuracies in delineating areas subject to erosion and deposition (as discussed above) and the approximate representation of the IR remedial alternative footprints necessitated by the low resolution of the model grid, causing individual model grid cells in the upper 9 miles to typically include remediated and unremediated areas. Additional model uncertainty results from simplifying assumptions made to delineate footprints from conditional simulation maps and resuspension during dredging.

The inability to represent remedial footprints accurately means that the model cannot represent the change in bed grain size and erodibility that would occur when the bed is capped after dredging. Bounding assumptions were made to generate projections bracketing the likely impact of capping. Projections were made with no change in bed characteristics and erodibility (and no release of solids during dredging) and with bed characteristics and erodibility changed for entire cells in which the remedy footprint encompassed half or more of the cell (including the release of solids during dredging). The former is termed MNR ST, and the latter is termed Scenario-specific ST because sediment transport differs for each scenario to which the model was applied. The model projections are sensitive to the representation of dredging and capping in the ST model, as demonstrated by the results presented in Appendix C.

An evaluation of the sensitivity of model projections to map selection (and resulting remedial footprints, as discussed in Section 8.2.1) shows that the model projections following completion of an IR are not highly sensitive to the map selection. The evaluation is presented in Appendix C.

Model projections have additional uncertainty that is derived from uncertainties associated with other parameters and assumed conditions. Notable among these are the sequence of low and high flows in the hydrograph and the dredging sequence. These were not formally evaluated, but diagnostic runs of the model not shown here have illustrated their importance and signify that the uncertainty considered in this IR FS likely underrepresents the true uncertainty of the projections.

The models will be refined during the remedial design, with data collected during the Current Conditions and PDI sampling to reduce the uncertainty in the projections and better represent the remedial actions using a higher resolution grid. A detailed discussion of model uncertainty can be found in Appendix C.

[63] The initial calibration of the bioaccumulation model for the LPRSA has not been completed, and EPA has determined that it requires a peer review prior to being used. As such, it is not utilized in this IR FS.

8.2.5 Consideration of Model Uncertainty in Evaluation of Model Projections

Given the sensitivity of model projections to the uncertainty in model inputs and parameterization discussed above, and consistent with the modeling guidelines (Section 6.2), model projections that are used to support evaluation of the NCP balancing criteria in the IR FS are presented as ranges. The ranges established to characterize the model projections were based on two of the areas of model uncertainty discussed above, for the purposes of comparison of alternatives in the IR FS. These ranges do not necessarily encompass the full range of factors contributing to model uncertainty. To establish ranges, four model projections were considered:

1. MNR ST projections (no change in bed characteristics and erodibility) and 1 percent contaminant release rate (without concurrent solids release)
2. MNR ST projections (no change in bed characteristics and erodibility) and 3 percent contaminant release rate (without concurrent solids release)
3. Scenario-specific ST projections (bed characteristics and erodibility changed for entire cells in which the remedy footprint encompassed half or more of the cell) and 1 percent contaminant release rate (with concurrent solids release)
4. Scenario-specific ST projections (characteristics and erodibility changed for entire cells in which the remedy footprint encompassed half or more of the cell) and 3 percent contaminant release rate (with concurrent solids release)

These model projections were used to calculate the range of the projections, where the maximum and minimum results from the four projection runs were selected for each metric to represent the range (e.g., for average annual metrics, the average annual projection was calculated for all model runs, and the minimum and maximum for each year was selected to represent the model projection range). Model projections for the remedial alternatives are presented and discussed as ranges in the detailed and comparative analysis.

8.2.6 Cost Estimate Uncertainty

The upper 9-mile IR FS cost estimate has significant scope and bid uncertainties due to the scope and scale of the project and the conceptual level of engineering analysis performed at the FS stage of a remediation projection. This uncertainty supports the selection and use of the 25 percent contingency factor in the cost estimate (USEPA 2000a). Major scope uncertainties may include:

- Remedy approach changes in the ROD or remedial design
- Area of the final remedial footprint needed to achieve RAOs following the PDI

- Dredging depth (including overdredge allowance) needed to accommodate final cap design
- Selection of dredged material transportation options and landfill type
- Extent of operations, maintenance, and monitoring (OMM) activities (e.g., sample collection, cap maintenance)
- Additional regulatory requirements.

Bid uncertainties may arise from:

- Unforeseen dredging challenges (hardpan, debris, utilities, etc.)
- Major delays due to external factors (e.g., bridge failure, extreme weather events)
- Changes in regulatory requirements during the project
- Market condition variations that affect pricing of goods and services.

Consistent with CERCLA, the IR FS cost estimate represents a –30/+50 percent level estimate, as appropriate for an FS, even with the cost refinement that would be performed for the dredging without capping evaluation (Section 7.1.1). Major changes in the scope, timing, and implementation of remedial action on the LPR may result in cost impacts that are outside of this range.

8.3 DETAILED EVALUATION OF THE ALTERNATIVES

The remedial alternatives are evaluated to assess their performance and degree of achievement of the NCP threshold criteria and primary balancing criteria.

8.3.1 Alternative 1: No Action

Alternative 1 involves no further active remediation in the upper 9-mile reach of the LPRSA. The evaluation of this alternative incorporates the Phase 1 removal action, the RM 10.9 time-critical removal action, and the planned lower 8-mile remedial action. Although this alternative does not meet the RAOs, it has been evaluated for comparison with the other alternatives.

8.3.1.1 Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 1 would not attain the RAOs and is not expected be protective of human health and the environment without implementation of additional source control measures, and does not have the ability to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and the water column. Alternative 1 does not include any

active remediation in the RM 8.3 to RM 15 reach and does not address ongoing sources that are inhibiting recovery.

Compliance with ARARs

Alternative 1 would comply with ARARs to the extent that no action- or location-specific ARARs would be triggered.

8.3.1.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence are evaluated as the degree to which the alternative achieves source control and recovery potential, monitoring, maintenance, and institutional controls.

Source Control and Recovery Potential

Alternative 1 does not include any active remediation in the RM 8.3 to RM 15 reach and does not provide source control beyond that provided by the RM 10.9 time-critical removal action completed in 2014. Alternative 1 has a low potential to provide recovery sufficient to meet the RGs that will be established under a final ROD.

Cap Stability

Alternative 1 does not provide for any capping.

Monitoring, Maintenance, and Institutional Controls

Alternative 1 would rely on existing institutional controls that would remain in place in perpetuity.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 1 does not reduce toxicity, mobility, or volume of contaminated sediment through treatment.

Short-Term Effectiveness

Evaluation of short-term effectiveness and impacts of Alternative 1 includes time to achieve RAOs, worker risks and community impacts, resuspension of dredged sediment during implementation, and transport of dredged sediment during implementation.

Time to Achieve RAOs

Alternative 1 does not achieve the RAOs.

Worker Risks and Community Impacts

Alternative 1 does not include any active construction and therefore does not incur any short-term worker risks or community impacts.

Resuspension

Alternative 1 does not include any active construction, and therefore does not cause any resuspension of contaminated sediment.

Downstream and Upstream Transport

Alternative 1 does not include any active construction, and therefore does not have any short-term impacts on upstream or downstream transport.

Implementability

Alternative 1 is implementable with no constraints or challenges, and would not require application of BMPs.

Cost

There is no cost associated with Alternative 1 (Table 8-4).

8.3.2 Alternative 2: 2,3,7,8-TCDD Target SWAC of 85 ng/kg, Total PCBs RAL of 1 mg/kg

Alternative 2 includes dredging and capping to attain a 2,3,7,8-TCDD target SWAC of 85 ng/kg and meet a total PCBs RAL of 1 mg/kg, as described in Section 7.3.2. The evaluation of this alternative incorporates the Phase 1 removal action, the RM 10.9 time-critical removal action, and the planned lower 8-mile remedial action. In the following sections, Alternative 2 is evaluated against the threshold and primary balancing criteria.

8.3.2.1 Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 2 would achieve the source control goals established in the IR RAOs and would meet the IR FS metric of ability to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations. Remediation of sediment within the remedial footprint for Alternative 2 can be anticipated to achieve the following:

- Attainment of RAO 1, post-IR target SWACs of 85 ng/kg for 2,3,7,8-TCDD and of 0.46 mg/kg for total PCBs (subject to post-construction confirmation upon completion of the IR in accordance with the IR remedy completion framework [Appendix H])
- Removal of sediment with the highest concentrations of 2,3,7,8-TCDD and total PCBs, reducing ongoing potential sources of legacy sediment contamination into the water column and biota
- Reduction of 2,3,7,8-TCDD surface sediment SWAC of approximately 91 percent, from 932 ng/kg[64] to 80 ng/kg and reduction of total PCBs surface sediment SWAC of approximately 81 percent, from 1.5 mg/kg to 0.29 mg/kg (Table 7-2)
- Ongoing recovery of surface sediment concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants following IR completion
- Ongoing recovery of surface water concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants
- Recovery of fish tissue concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants resulting from reduced concentrations in sediment and the water column
- Reduced potential for human health and the ecosystem exposure to 2,3,7,8-TCDD, total PCBs, and other contaminants resulting from SWAC and water column concentration reductions.

Compliance with ARARs

Alternative 2 can be designed and implemented to comply with all substantive location- and action-specific ARARs. Alternative 2 could require one or more ARAR waivers during construction to meet threshold criterion of compliance with ARARs.

Alternative 2 is anticipated to comply with the ARARs through appropriate engineering design and agency review processes. Confirmation of ARARs compliance is typically demonstrated during remedial design and through the remedial action work plan (e.g., environmental protection plan, construction quality control plan, waste management plan, transportation and disposal plan, stormwater pollution and spill prevention plan, and BMPs) as well as monitoring during the construction period.

A final remedy for surface water[65] will be established in the final ROD for the entire OU4. While the IR is anticipated to improve water quality, ARARs for water quality may not be achieved following completion (see Section 4.2.1); however, no evaluation of the potential need for a technical impracticability waiver (TI waiver) was performed as part of the IR FS.

[64] Initial SWACs based on CS 37 mapped to the model grid; see Appendix C.
[65] The final remedy will also address any remaining site risks in the upper 9 miles.

8.3.2.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Evaluation metrics for long-term effectiveness and permanence are source control and recovery potential; cap stability; and monitoring, maintenance, and institutional controls (Table 8-1).

Source Control and Recovery Potential

Implementation of Alternative 2 would achieve source control and result in a high potential for accelerated recovery, as discussed below in the evaluation of Alternative 2 against the source control and recovery potential metrics (Table 8-1). See Section 8.1.4.2 for a discussion of the individual metrics.

Efficacy of RALs based on the CSM

Under the estimated technical specifications for Alternative 2 (Table 7-1), removal and capping of sediment to address RAO 1 and RAO 2 are estimated to achieve a post-construction surface sediment SWAC of 80 ng/kg for 2,3,7,8-TCDD and 0.29 mg/kg for total PCBs (Table 7-2). This is achieved by remediation of surface sediment with concentrations higher than RALs of 260 ng/kg for 2,3,7,8-TCDD and 1 mg/kg for total PCBs, along with additional remediation of areas vulnerable to erosion with concentrations in the 0.5–1.5 ft depth interval that are higher than 2 times the corresponding surface RALs, as described in Appendix B. Implementation of the Alternative 2 RALs would result in removal of sediment that is impeding recovery, based on the evaluation of water column particulate concentrations evaluated in the CSM for natural recovery (Section 2.6). The 2,3,7,8-TCDD RAL under Alternative 2 falls within the lower third of the estimated 200 to 400 ng/kg concentration range for water column particles depositing on the sediment surface, and the total PCBs RAL of 1 mg/kg similarly reflects the current understanding of water column particulate concentrations for total PCBs. Alternative 2 would thereby effectively address sources of 2,3,7,8-TCDD and total PCBs in surface and subsurface sediment and achieve the source control goals of an IR established under RAO 1 and RAO 2.

Areas, masses, and volumes of source removal

Implementation of Alternative 2 would remove 363,000 cy of sediment from an area of 90 acres within the site (Table 7-1). The estimated mass of contaminants removed in the upper 0.5 ft of the sediment bed (the relevant depth interval for human health and ecological exposure) is approximately 123 g of 2,3,7,8-TCDD (of the approximate total of 133 g in RM 8.3 to RM 15[66]; Table 8-7) and approximately 161 kg of total PCBs (of the approximate total of 197 kg in RM 8.3 to RM 15; Table 8-7).

[66] The estimated mass removed for each alternative and mass in RM 8.3 to RM 15 is based on the 2010 mapping interpolations described in Appendix J of the RI report (AQEA 2019). An average bulk density of 0.848 g/cm^3 was used for each of the CS 37 node concentrations.

Distribution of post-IR concentrations relative to pre-IR concentrations

Figures 8-1a and 8-2a compare the mapped surface sediment concentrations prior to and following the implementation of Alternative 2, and Figures 8-3 and 8-4 show the distribution of surface contaminant concentrations pre- and post-implementation for 2,3,7,8-TCDD and total PCBs, respectively. These figures show that the highest concentrations of 2,3,7,8-TCDD and total PCBs would be removed throughout the upper 9 miles and that the distribution of concentrations of 2,3,7,8-TCDD and total PCBs would shift towards lower values.

Model projections of average sediment concentrations and recovery half-life

In the 10 years following completion of an IR, implementation of Alternative 2 is projected to result in a significant reduction in projected sediment SWACs of 2,3,7,8-TCDD and total PCBs in the upper 9 miles (RM 8.3 to RM 15), compared with the SWAC at model initiation (i.e., before implementation of the lower 8-mile remedial action and the upper 9-mile source control IR; Figures 8-6 and 8-7, panel a). In year 10 following IR completion (model year 18), the SWACs are considerably lower than the No Action alternative (Figures 8-6 and 8-7, panel b; Table 8-8).

The implementation of Alternative 2, together with the lower 8-mile remedy, is projected to result in significant SWAC reductions overall in the LPR. In the lower 8 miles (RM 0 to RM 8.3), Alternative 2 post-IR sediment SWACs of 2,3,7,8-TCDD and total PCBs are lower than the lower 8-mile SWACs at model initiation (i.e., pre-IR SWAC; Figures 8-8 and 8-9, panel a). River-wide (RM 0 to RM 15), implementation of Alternative 2 is projected to provide additional reduction in SWACs compared with implementation of the lower 8-mile remedy alone (Alternative 1) (Figures 8-10 and 8-11, panels a,b; Table 8-8). While reductions in sediment concentrations in the lower 8 miles are primarily influenced by the implementation of the lower 8-mile remedial action, model projections suggest a longer-term benefit to lower-8-mile SWAC reduction at the end of the 10-year period (model year 18) from source control implementation in the upper 9 miles (Figures 8-8 and 8-9, panel b; Table 8-8).

The projected SWAC reductions resulting from the implementation of Alternative 2 in the upper 9 miles and river-wide result from the removal of high concentrations of 2,3,7,8-TCDD and total PCBs in sediment to control sources. The control of sources would accelerate the recovery of the water column and unremediated sediment.

The estimated recovery half-life of the projected sediment SWACs (i.e., the time to reduce the initial post-IR SWAC by 50 percent[67]) is presented in Figure 8-12. The 2,3,7,8-TCDD SWAC half-life ranges from approximately 8 to 18 years (Table 8-8), compared with the recovery half-life of the No Action alternative of approximately 125 to 244 years (where a lower number means faster recovery of the sediment SWACs). The total PCB SWAC recovery half-life ranges

[67] The recovery half-life is calculated relative to the alternative-specific SWAC at the end of model year 8; the SWAC achieved after one half-life is therefore much lower for Alternative 2 than for Alternative 1. See Appendix C for a discussion of the half-life calculation.

from approximately 18 to 46 years, compared with the recovery half-life of the No Action alternative of approximately 79 to 110 years. The significant reduction in projected half-life under Alternative 2 confirms the effectiveness of an IR to achieve source control and promote accelerated recovery.

Model projections of average water column concentrations

Projected water column concentrations of 2,3,7,8-TCDD and total PCBs fluctuate in the 10-year period following completion of Alternative 2 (Figures 8-13 and 8-14, panel a); these fluctuations are clearly tied to the modeled hydrograph (Figure 8-5), as they are evident in all alternatives, including the No Action alternative. Averaged over the 10-year post-IR period, 2,3,7,8-TCDD water column concentrations under Alternative 2 are approximately 22 to 25 percent of the water column concentrations under the No Action alternative (Figure 8-13, panel b; Table 8-8). The 10-year post-IR average water column concentration of total PCBs under Alternative 2 shows a smaller, but discernible, reduction relative to the No Action alternative, due to the influence of background concentrations entering the LPR at Dundee Dam and from tributaries (Figure 8-14, panel b; Table 8-8). The reduction in water column concentrations results from the control of sediment sources, and will subsequently result in recovery of unremediated sediment.

Model projections of average and cumulative water column loads

Over the 10 years following completion of an IR, the implementation of Alternative 2 would result in a reduction of net water column contaminant load moving out of the upper 9 miles (at RM 8.3) of the LPR, as shown by model projections of 2,3,7,8-TCDD and total PCBs annual water column load at RM 8.3 (Figures 8-16 and 8-20, panels a,b; Table 8-8) and RM 0 (Figures 8-17 and 8-21, panels a,b). Projected loads fluctuate over time, corresponding to the peak flows seen in the hydrograph used in the projections (Figure 8-5). Over the 10 years following completion of an IR, the projected total water column load leaving the upper 9 miles (at RM 8.3) is approximately 6.8 to 9.0 g of 2,3,7,8-TCDD, and approximately 135 to 138 kg of total PCBs (Figures 8-18 and 8-22, panel b; Table 8-8). Implementation of Alternative 2 is not projected to materially affect net downstream water column loads at RM 15 (Figures 8-15 and 8-19). The reduction in water column loads results from the control of sediment sources and associated reduction in water column concentrations.

Model projections of average net and gross contaminant erosional flux

Projected sediment contaminant erosional fluxes fluctuate over the 10-year post-IR period (Figures 8-23 to 8-26, panel a). Projected fluctuations are tied to the hydrograph (Figure 8-5) and projected total PCB erosional fluxes are influenced by background concentrations. The erosional fluxes averaged over the 10-year post IR period are lower for Alternative 2 compared with the No Action alternative (Figures 8-23 to 8-26, panel b; Table 8-8), indicating a reduction of contaminant mass entering the water column, which would reduce the redistribution of contaminants within the RM 8.3 to RM 15 reach and reduce contaminant mass moving

downstream (as evidenced in the reduction of water column load). The similar reductions in gross and net erosional 2,3,7,8-TCDD flux indicate that the removal of sediment under Alternative 2 removes the dominant sources of 2,3,7,8-TCDD (i.e., addressing sources reduces erosional flux which in turn reduces depositional flux). For total PCBs, the reduction in net flux under Alternative 2 is greater than the reduction in gross flux compared with the No Action alternative. Addressing source areas reduces erosion within the IR reach, but due to ongoing sources of total PCBs originating upstream of the LPRSA, depositional flux is not reduced to the same extent, which causes the gross erosion from sediment in the RM 8.3 to RM 15 reach to continue at levels that are closer to Alternative 1 for total PCBs than for 2,3,7,8-TCDD. The reduction in the magnitude of contaminant erosional loadings to the water column within the IR reach will result in ongoing recovery of the water column and sediment.

Model projections of contaminant concentrations on depositing fine sediment

Model projections of annual average concentrations of 2,3,7,8-TCDD on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 2 are roughly constant (Figure 8-27, panel a), with the exception of the first two years (model years 9 and 10), which likely indicates that the system is still responding to the dredging. Model projections of annual average concentrations of total PCBs on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 2 show some decline following the first two years (Figure 8-28, panel a). The average projected concentration of 2,3,7,8-TCDD on depositing fine sediment over the 10-year post-IR period ranges from 24 to 29 ng/kg, compared with 111 to 117 ng/kg for the No Action alternative (Figure 8-27, panel b; Table 8-8). The average projected concentration of total PCBs on depositing fine sediment over the 10-year post-IR period ranges from 0.43 to 0.45 mg/kg, compared with approximately 0.54 mg/kg under the No Action alternative (Figure 8-28, panel b; Table 8-8). The projected reduction in concentration on depositing fines is consistent with the CSM: that removal of source sediment under Alternative 2 will reduce concentrations on depositing fines and thereby accelerate recovery of unremediated sediment.

Cap Stability

Alternative 2 includes capping throughout the remedial footprint, to a thickness equal to the depth of sediment removal (2 ft dredge depth plus 0.5 ft overdredge). The conceptual cap design (Appendix F) includes an isolation layer consisting of sand amended with activated carbon, an armor layer to resist up to a 100-year-flood event, and a surface layer of habitat substrate in the shoals. Based on subsurface sediment parameters, predicted contaminant breakthrough of the cap would not occur within 100 years. The conceptual cap evaluation demonstrates that a stable cap capable of providing long-term protectiveness can be implemented to isolate contaminated sediment left in place following implementation of an IR.

Monitoring, Maintenance, and Institutional Controls

During implementation of an IR, Alternative 2 would require construction monitoring to verify horizontal and vertical sediment cut lines, sediment sampling to evaluate the efficacy of residual management measures, bathymetry surveys to verify proper cap placement, and water column sampling to ensure minimal resuspension and residual impacts. Following completion of an IR, Alternative 2 would require sediment sampling and consideration of other lines of evidence to confirm that the implementation of the remedy is complete and that it has achieved the RAOs and met other remedial design requirements (e.g., appropriate cap placement). Sediment sampling would be performed within and outside of the remedial footprint. The framework for confirmation of remedy completion is presented in Appendix H.

Alternative 2 would require long-term monitoring following completion of an IR as part of an adaptive management program to assess system response and recovery and eventually to ensure that the final RGs established in a final ROD have been achieved. Long-term monitoring would be required throughout the 9-mile reach, and would be anticipated to include tissue, water column, and sediment sampling to assess system recovery and progress toward attainment of RGs. It is assumed that long-term monitoring would continue for 30 years after construction is complete. Issuance of a final ROD would replace the monitoring and maintenance requirements of the IR. An initial Adaptive Management Implementation Approach for the upper 9 miles of the LPRSA is presented in Appendix D.

Cap monitoring would be required for Alternative 2 following an IR to assess the performance and stability of the cap. It is anticipated that periodic cap maintenance could be required. Cap monitoring would be performed over the extent of the capped area in Alternative 2, which is assumed to be the same as the remedial footprint of 90 acres. For the IR FS, it is assumed that the Alternative 2 capped area would require maintenance proportional to its volume over the 30-year period. The IR FS cost estimate assumes that 5 percent of the cap would be replaced every 5 years for the first 20 years after construction, and 2.5 percent of the cap would be replaced every 5 years for the following 10 years.

Alternative 2 would rely on institutional controls. Existing institutional controls would be retained until RGs are achieved, at which time there could be revisions to fish consumption advisories. Alternative 2 would require additional controls in perpetuity to protect the integrity of the cap following completion of construction, unless and until some future remedy would address all site risks and allow for the removal of controls.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 2 would include removal, disposal, and containment to reduce contaminant toxicity and mobility. Contaminants would be treated *ex situ* by stabilization during sediment processing, and *in situ* by the organic carbon content of the cap.

Dredged sediment would be solidified and stabilized via treatment with a reagent admixture (e.g., Portland cement), which would reduce toxicity and mobility before disposal. The reagent would solidify the sediment by reducing the water content to levels appropriate for transportation and disposal at a permitted landfill. Chemical stabilization by the reagent would further immobilize contaminants within the dredged sediment. Solidification and stabilization are considered irreversible, but this component of treatment does not address residuals that would remain in the LPR. An *in situ* sediment volume of 363,000 cy would be solidified and stabilized *ex situ* at a nearby commercial processing facility. Implementation of Alternative 2 would result in removal of approximately 590 g of 2,3,7,8-TCDD (of the approximate total of 740 g in upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7) and approximately 810 kg of total PCBs (of the approximate total of 1,270 kg in upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7).

The conceptual sediment cap design for Alternative 2 (Appendix F) specifies 5 percent organic carbon content in the sand isolation layer, which would reduce the mobility of residual contaminants in the 90-acre remedial footprint of Alternative 2. Organic carbon in the cap would inhibit potential contaminant movement through the cap and be designed to prevent cap breakthrough within 100 years of placement. Capping is considered to be permanent, and the remaining residuals within the dredge footprint would be covered. Remaining contamination is expected to be effectively sequestered by this treatment action.

ENR and *in situ* sediment treatment options have been retained for consideration in the remedial design, and, if implemented, would sequester contaminants in areas where active dredging and capping are not possible (e.g., utility crossings, bridge abutments, and critical shoreline structures).

Short-Term Effectiveness

Evaluation of short-term effectiveness and impacts of Alternative 2 includes time to achieve RAOs, worker risks and community impacts, resuspension of dredged sediment during implementation, and transport of dredged sediment during implementation.

Time to Achieve RAOs

Alternative 2 is anticipated to achieve the RAOs in 7.3 years following the start of construction. It is anticipated that the IR completion assessment process will take approximately 3 years following the 4.3-year construction period, which includes implementation of post-IR sediment sampling, analysis of results, potential additional sampling to address uncertainty, and the decision-making process following completion of data collection activities.

Worker Risks and Community Impacts

As described above, Alternative 2 includes dredging and capping of 90 acres over an estimated 4.3 years, removing 363,000 cy of contaminated sediment in the upper 9 miles of the LPR. Dredge and cap material would be transported by barge to and from the site. All dredged materials would be disposed offsite. Short-term impacts related to construction duration, footprint size, and removal volume are as follows:

- Potential impacts during operations would occur during a 6-month construction season, July 1 to December 31, each year of construction, with operation 24 hours per day, 6 days per week (see Appendix A for specific assumptions on construction season). As noted in Appendix A, construction is assumed not to occur during an annual winter shutdown, January 1 to March 1, or during the dredging restriction period associated with the fish migration window, March 1 to June 30.
- Potential short-term worker risks during the construction period include construction hazards from the use of heavy machinery, open water, and exposure to contaminated sediment. A site-specific health and safety plan would be developed to mitigate risks.
- Potential short-term community impacts during the construction period include vehicular delays as a result of bridge closures, road closures, and railroad crossings due to the transportation of dredged sediment and cap material; locally increased traffic as workers access the construction site, which could increase rate of traffic incidents/ accidents; and light pollution, noise, exhaust, and odor from equipment and 24-hour operations. Although these short-term impacts are unlikely due to proposed institutional controls, exposure to the contaminants could occur with river recreation from direct contact, inhalation, or ingestion of surface waters or contaminated sediment.
- During the active construction period, operations would require property for a 5-acre upland support facility to be used for contractor trailers, sample processing, equipment storage, and parking.[68]
- Habitat and ecological disturbance would occur within the remedial footprint and over the construction duration. Implementation of Alternative 2 would include the restoration of disturbed habitat, and restoration activity would likely be implemented following construction. Therefore, there could be short-term ecological effects within the remedial footprint beyond construction duration and prior to completion of restoration activities. BMPs would be applied to minimize disturbances to the ecosystem and wildlife habitats from the dredging and capping activities outside of the remedial footprints. The impacts from dredging and capping would be primarily from sediment disturbances and resuspension, and potentially from increased noise, exhaust, or river traffic. In addition, marsh disturbances could occur as a result of river bank instability.

[68] Identification of potential suitable parcels for the upland support facility would be performed during the early stages of the remedial design.

Contractor access to the waterway for land-based dredging and capping could impact the benthic habitat in the shoals.

Resuspension

The implementation of Alternative 2 would result in sediment resuspension and contaminant release into the water column during construction that could result in short-term exposure of humans or biota to increased concentrations of 2,3,7,8-TCDD, total PCBs, and other collocated contaminants. It is anticipated that, during design, the potential for resuspension and release to result in recontamination would be evaluated, and BMPs would be designed and implemented to reduce or eliminate the negative impacts on source control and achievement of the RAOs (Section 7.1.3).

The model projections for Alternative 2 evaluate dredging scenarios where either 1 or 3 percent of the dredged sediment is released into the water column, and the model does not simulate near-field settling of particles within the vicinity of the dredge or BMPs that would control residual transport. The model projections show that water column concentrations of 2,3,7,8-TCDD and total PCBs would be higher during construction of Alternative 2 compared with the No Action alternative (Figure 8-29), with concentrations varying temporally, driven by both the hydrograph in the models and the assumed dredge sequence and associated concentrations in the dredged sediment. Most of the highest sediment concentrations in the remedial footprint are located between RM 8.3 and RM 10, and the dredge sequencing used in the models addresses this sediment in the latter 2 years of construction. The model projections also show that, following completion of construction, water column concentrations settle down to a level below pre-construction concentrations.

Downstream and Upstream Transport

The implementation of Alternative 2 would result in increased downstream transport of 2,3,7,8-TCDD and total PCBs at RM 8.3 that could result in short-term exposure of humans or biota to increased concentrations during construction below RM 8.3 (Figures 8-30 and 8-32). Projected water column fluxes in this period are also influenced by the hydrograph that is used in the models, the assumed dredge sequence, as well as the construction in the lower 8 miles. Total water column load at RM 8.3 over the construction period is projected to be approximately 37 to 46 g of 2,3,7,8-TCDD (Figure 8-31), and approximately 129 to 145 kg of total PCBs (Figure 8-33). The implementation of Alternative 2 is not projected to increase transport at RM 0 or RM 15 during construction.

Implementability

Alternative 2 includes dredging of approximately 363,000 cy of sediment, followed by placement of an approximate equivalent volume of capping material. Dredged sediment would be transported to a treatment facility for processing, followed by transport to an offsite disposal

facility. The technologies and methods to complete this work are well-established. Necessary equipment (including custom equipment), materials, facilities, and transportation capacity would be available with sufficient lead times.

BMPs would be required during the construction of Alternative 2 to manage dredge residuals and recontamination (Sections 7.1.3 and 8.2.2).

Construction challenges and constraints would be expected to be significant for Alternative 2, given the urban environment of the LPR. Utility crossings, bridge abutments, and critical shoreline structures, discussed in Section 2.3 and Appendix E, could limit or prohibit active dredging and capping in some areas of the Alternative 2 remedial footprint. Dredge offsets and/or engineering controls may be required to protect shoreline structures. In those areas, ENR and/or *in situ* sediment treatment may be evaluated for implementability and effectiveness during remedial design.

Numerous low bridge crossings and other navigational constraints may necessitate specialty, low-profile vessels to move equipment and materials up and down the river, and frequent bridge openings proportionate to the number of projected barge trips for each alternative, to allow barges and tugs to pass. As evidenced during the RM 10.9 and Phase 1 removal actions (Appendix E), inoperable bridges resulted in significant construction delays. The need for custom equipment, and more generally the optimal methods for material transport, would be evaluated during remedial design to address these constraints and challenges.

Alternative 2 is anticipated to be administratively feasible; however, coordinating with property owners and local governments and obtaining permit equivalents can be anticipated to be time consuming, given the magnitude of the remedy, with the potential to delay construction.

Alternative 2 would be designed to accommodate future anticipated uses of the upper 9 miles of the LPR, including access by waterfront visitors and in-water recreational users.

The in-water construction for the lower 8-mile remedial action is scheduled to begin mid-2022. It is assumed that Alternative 2 implementation would begin in 2024, and the construction periods of the two actions would overlap by several years. Given the estimated schedule, there would be opportunity in the implementation of Alternative 2 to take advantage of any lessons learned during the lower 8-mile remedial design and initial years of remedial construction. Further, there may be opportunities to use common resources (e.g., sediment processing facilities or specialized equipment). The technical and administrative feasibility of such opportunities would be explored during remedial design.

Cost

The total estimated present value cost of Alternative 2 is $420 million (Table 8-4). Costs include the PDI, remedial design, direct and indirect capital costs, and annual and periodic OMM costs

for 30 years after the end of construction. The direct capital, annual OMM, and periodic costs include a 25 percent contingency factor to address scope and bid uncertainty (Section 8.2.5). Costs are presented on a net present value basis using a discount rate of 7 percent. The detailed cost estimate for Alternative 2 is provided in Appendix G.

A cost sensitivity analysis presented in Table 8-5 shows the sensitivity of the total estimated cost to discount rates and contingency assumptions. Costs are presented undiscounted and with discount rates of 7 percent and 1.5 percent (a reasonable expected discount rate for a 30-year project based on information published by the OMB [2018]). Contingency factors of 25 and 35 percent are presented.

8.3.3 Alternative 3: 2,3,7,8-TCDD Target SWAC of 75 ng/kg, Total PCBs RAL of 1 mg/kg

Alternative 3 includes dredging and capping to attain a 2,3,7,8-TCDD target SWAC of 75 ng/kg and meet a total PCBs RAL of 1 mg/kg, as described in Section 7.3.3. The evaluation of this alternative incorporates the Phase 1 removal action, the RM 10.9 time-critical removal action, and the planned lower 8-mile remedial action. In the following sections, Alternative 3 is evaluated against the threshold and primary balancing criteria.

8.3.3.1 Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 3 would achieve the source control goals established in the IR RAOs and would meet the IR FS metric of ability to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations. Remediation of sediment within the remedial footprint for Alternative 3 can be anticipated to achieve the following:

- Attainment of RAO 1, post-IR target SWACs of 85 ng/kg for 2,3,7,8-TCDD and of 0.46 mg/kg for total PCBs (subject to post-construction confirmation upon completion of the IR in accordance with the IR remedy completion framework [Appendix H])
- Removal of sediment with the highest concentrations of 2,3,7,8-TCDD and total PCBs, reducing ongoing potential sources of legacy sediment contamination into the water column and biota
- Reduction of 2,3,7,8-TCDD surface sediment SWAC of approximately 92 percent, from 932 ng/kg[69] to 70 ng/kg and reduction of total PCBs surface sediment SWAC of approximately 82 percent, from 1.5 mg/kg to 0.27 mg/kg (Table 7-2)

[69] Initial SWACs based on CS 37 mapped to the model grid; see Appendix C.

- Ongoing recovery of surface sediment concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants following IR completion
- Ongoing recovery of surface water concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants
- Recovery of fish tissue concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants resulting from reduced concentrations in sediment and the water column
- Reduced potential for human health and the ecosystem exposure to 2,3,7,8-TCDD, total PCBs, and other contaminants resulting from SWAC and water column concentration reductions.

Compliance with ARARs

Alternative 3 can be designed and implemented to comply with all substantive location- and action-specific ARARs. Alternative 3 could require one or more ARAR waivers during construction to meet threshold criterion of compliance with ARARs.

Alternative 3 is anticipated to comply with the ARARs through appropriate engineering design and agency review processes. Confirmation of ARARs compliance is typically demonstrated during remedial design and through the remedial action work plan (e.g., environmental protection plan, construction quality control plan, waste management plan, transportation and disposal plan, stormwater pollution and spill prevention plan, and BMPs) as well as monitoring during the construction period.

A final remedy for surface water[70] will be established in the final ROD for the entire OU4. While the IR is anticipated to improve water quality, ARARs for water quality may not be achieved following completion (see Section 4.2.1); however, no evaluation of the potential need for a TI waiver was performed as part of the IR FS.

8.3.3.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Evaluation metrics for long-term effectiveness and permanence are source control and recovery potential; cap stability; and monitoring, maintenance, and institutional controls (Table 8-1).

Source Control and Recovery Potential

The implementation of Alternative 3 would achieve source control and result in a high potential for accelerated recovery, as discussed below in the evaluation of Alternative 3 against the

[70] The final remedy will also address any remaining site risks in the upper 9 miles.

source control and recovery potential metrics (Table 8-1). See Section 8.1.4.2 for a discussion of the individual metrics.

Efficacy of RALs based on the CSM

Under the estimated technical specifications for Alternative 3 (Table 7-1), removal and capping of sediment to address RAO 1 and RAO 2 are estimated to achieve a post-construction surface sediment SWAC of 70 ng/kg for 2,3,7,8-TCDD and 0.27 mg/kg for total PCBs (Table 7-2). This is achieved by remediation of surface sediment with concentrations higher than RALs of 205 ng/kg for 2,3,7,8-TCDD and 1 mg/kg for total PCBs, along with additional remediation of areas vulnerable to erosion with concentrations in the 0.5–1.5 ft depth interval that are higher than 2 times the corresponding surface RALs, as described in Appendix B. Implementation of the Alternative 3 RALs would result in removal of sediment that is impeding recovery, based on the evaluation of water column particulate concentrations evaluated in the CSM for natural recovery (Section 2.6). The 2,3,7,8-TCDD RAL under Alternative 3 falls at the low end of the estimated 200 to 400 ng/kg concentration range for water column particles depositing on the sediment surface, and the total PCBs RAL of 1 mg/kg similarly reflects the current understanding of water column particulate concentrations for total PCBs. Alternative 3 would thereby effectively address sources of 2,3,7,8-TCDD and total PCBs in surface and subsurface sediment and achieve the source control goals of an IR established under RAO 1 and RAO 2.

Areas, masses, and volumes of source removal

Implementation of Alternative 3, would remove 387,000 cy of sediment from an area of 96 acres within the site (Table 7-1). The estimated mass of contaminants removed in the upper 0.5 ft of the sediment bed (the relevant depth interval for human health and ecological exposure) is approximately 124 g of 2,3,7,8-TCDD (of the approximate total of 133 g in RM 8.3 to RM 15[71]; Table 8-7) and approximately 163 kg of total PCBs (of the approximate total of 197 kg in RM 8.3 to RM 15; Table 8-7).

Distribution of post-IR concentrations relative to pre-IR concentrations

Figures 8-1b and 8-2b compare the mapped surface sediment concentrations prior to and following the implementation of Alternative 3, and Figures 8-3 and 8-4 show the distribution of surface contaminant concentrations pre- and post-implementation for 2,3,7,8-TCDD and total PCBs, respectively. These figures show that the highest concentrations of 2,3,7,8-TCDD and total PCBs would be removed throughout the upper 9 miles and that the distribution of concentrations of 2,3,7,8-TCDD and total PCBs would shift towards lower values.

[71] The estimated mass removed for each alternative and mass in RM 8.3 to RM 15 is based on the 2010 mapping interpolations described in Appendix J of the RI report (AQEA 2019). An average bulk density of 0.848 g/cm^3 was used for each of the CS 37 node concentrations.

Model projections of average sediment concentrations and recovery half-life

In the 10 years following completion of an IR, implementation of Alternative 3 is projected to result in a significant reduction in projected sediment SWACs of 2,3,7,8-TCDD and total PCBs in the upper 9 miles (RM 8.3 to RM 15), compared with the SWAC at model initiation (i.e., before implementation of the lower 8-mile remedial action and the upper 9-mile source control IR; Figures 8-6 and 8-7, panel a). In year 10 following IR completion (model year 18), the SWACs are considerably lower than the No Action alternative (Figures 8-6 and 8-7, panel b; Table 8-8).

The implementation of Alternative 3, together with the lower 8-mile remedy, is projected to result in significant SWAC reductions overall in the LPR. In the lower 8 miles (RM 0 to RM 8.3), Alternative 3 post-IR sediment SWACs of 2,3,7,8-TCDD and total PCBs are lower than the lower 8-mile SWACs at model initiation (i.e., pre-IR SWAC; Figures 8-8 and 8-9, panel a). River-wide (RM 0 to RM 15) implementation of Alternative 3 is projected to provide additional reduction in SWACs compared with implementation of the lower 8-mile remedy alone (Alternative 1) (Figures 8-10 and 8-11, panels a,b; Table 8-8). While reductions in sediment concentrations in the lower 8 miles are primarily influenced by the implementation of the lower 8 mile remedial action, model projections suggest a longer-term benefit to lower-8-mile SWAC reduction at the end of the 10-year period (model year 18) from source control implementation in the upper 9 miles (Figures 8-8 and 8-9, panel b; Table 8-8).

The projected SWAC reductions resulting from implementation of Alternative 3 in the upper 9 miles and river-wide result from the removal of high concentrations of 2,3,7,8-TCDD and total PCBs in sediment to control sources. The control of sources would accelerate the recovery of the water column and unremediated sediment.

The estimated recovery half-life of the projected sediment SWACs (i.e., the time to reduce the initial post-remedy SWAC by 50 percent[72]) is presented in Figure 8-12. The 2,3,7,8-TCDD SWAC half-life ranges from approximately 8 to 15 years (Table 8-8), compared with the recovery half-life of No Action alternative of approximately 125 to 244 years (where a lower number means faster recovery of the sediment SWACs). The total PCB SWAC recovery half-life ranges from approximately 17 to 43 years, compared with the recovery half-life of the No Action alternative of approximately 79 to 110 years. The significant reduction in projected half-life under Alternative 3 confirms the effectiveness of an IR to achieve source control and promote accelerated recovery.

Model projections of average water column concentrations

Projected water column concentrations of 2,3,7,8-TCDD and total PCBs fluctuate in the 10-year period following completion of Alternative 3 (Figures 8-13 and 8-14, panel a); these fluctuations

[72] The recovery half-life is calculated relative to the alternative-specific SWAC at the end of model year 8; the SWACs achieved after one half-life is therefore much lower for Alternative 3 than for Alternative 1. See Appendix C for a discussion of the half-life calculation.

are clearly tied to the modeled hydrograph (Figure 8-5), as they are evident in all alternatives, including the No Action alternative. Averaged over the 10-year post-IR period, 2,3,7,8-TCDD water column concentrations under Alternative 3 are approximately 21 to 24 percent of the water column concentrations under the No Action alternative (Figure 8-13, panel b; Table 8-8). The 10-year post-IR average water column concentration of total PCBs under Alternative 3 shows a smaller, but discernible, reduction relative to the No Action alternative, due to the influence of background concentrations entering the LPR at Dundee Dam and from tributaries (Figure 8-14, panel b; Table 8-8). The reduction in water column concentrations results from the control of sediment sources, and will subsequently result in recovery of unremediated sediment.

Model projections of average and cumulative water column loads

Over the 10 years following completion of an IR, the implementation of Alternative 3 would result in a reduction of net water column contaminant load moving out of the upper 9 miles (at RM 8.3) of the LPR, as shown by model projections of 2,3,7,8-TCDD and total PCBs annual water column load at RM 8.3 (Figures 8-16 and 8-20, panels a,b; Table 8-8) and RM 0 (Figures 8-17 and 8-21, panels a,b). Projected loads fluctuate over time, corresponding to the peak flows seen in the hydrograph used in the projections (Figure 8-5). Over the 10 years following completion of an IR, the projected total water column load leaving the upper 9 miles (at RM 8.3) is approximately 6.3 to 8.2 g of 2,3,7,8-TCDD and approximately 135 to 138 kg of total PCBs (Figures 8-18 and 8-22, panel b; Table 8-8). The implementation of Alternative 3 is not projected to materially affect net downstream water column loads at RM 15 (Figures 8-15 and 8-19). The reduction in water column loads results from the control of sediment sources and associated reduction in water column concentrations.

Model projections of average net and gross contaminant erosional flux

Projected sediment contaminant erosional fluxes fluctuate over the 10-year post-IR period (Figures 8-23 to 8-26, panel a). Projected fluctuations are tied to the hydrograph (Figure 8-5) and projected total PCB erosional fluxes are influenced by background concentrations. The erosional fluxes averaged over the 10-year post-IR period are lower for Alternative 3 compared with the No Action alternative (Figures 8-23 to 8-26, panel b; Table 8-8), indicating a reduction of contaminant mass entering the water column, which would reduce the redistribution of contaminants within the RM 8.3 to RM 15 reach and reduce contaminant mass moving downstream (as evidenced in the reduction of water column load). The similar reductions in gross and net erosional 2,3,7,8-TCDD flux indicate that the removal of sediment under Alternative 3 removes the dominant sources of 2,3,7,8-TCDD (i.e., addressing sources reduces erosional flux which in turn reduces depositional flux). For total PCBs, the reduction in net flux under Alternative 3 is greater than the reduction in gross flux compared with the No Action alternative. Addressing source areas reduces erosion within the IR reach, but due to ongoing sources of total PCBs originating upstream of the LPRSA, depositional flux is not reduced to the same extent, which causes the gross erosion from sediment in the RM 8.3 to RM 15 reach to

continue at levels that are closer to Alternative 1 for total PCBs than for 2,3,7,8-TCDD. The reduction in the magnitude of contaminant erosional loadings to the water column within the IR reach will result in ongoing recovery of the water column and sediment.

Model projections of contaminant concentrations on depositing fine sediment

Model projections of annual average concentrations of 2,3,7,8-TCDD on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 3 are roughly constant (Figure 8-27, panel a), with the exception of the first two years (model years 9 and 10), which likely indicates that the system is still responding to the dredging. Model projections of annual average concentrations of total PCBs on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 3 show some decline following the first two years (Figure 8-28, panel a). The average projected concentration of 2,3,7,8-TCDD on depositing fine sediment over the 10-year post-IR period ranges from 23 to 28 ng/kg, compared with 111 to 117 ng/kg for the No Action alternative (Figure 8-27, panel b; Table 8-8). The average projected concentration of total PCBs on depositing fine sediment over the 10-year post-IR period ranges from 0.43 to 0.45 mg/kg, compared with approximately 0.54 mg/kg under the No Action alternative (Figure 8-27, panel b; Table 8-8). The projected reduction in concentration on depositing fines is consistent with the CSM: that removal of source sediment under Alternative 3 will reduce concentrations on depositing fines and thereby accelerate recovery of unremediated sediment.

Cap Stability

Alternative 3 includes capping throughout the remedial footprint, to a thickness equal to the depth of sediment removal (2 ft dredge depth plus 0.5 ft overdredge). The conceptual cap design (Appendix F) includes an isolation layer consisting of sand amended with activated carbon, an armor layer to resist up to a 100-year-flood event, and a surface layer of habitat substrate in the shoals. Based on subsurface sediment parameters, predicted contaminant breakthrough of the cap would not occur within 100 years. The conceptual cap evaluation demonstrates that a stable cap capable of providing long-term protectiveness can be implemented to isolate contaminated sediment left in place following implementation of an IR.

Monitoring, Maintenance, and Institutional Controls

During implementation of an IR, Alternative 3 would require construction monitoring to verify horizontal and vertical sediment cut lines, sediment sampling to evaluate the efficacy of residual management measures, bathymetry surveys to verify proper cap placement, and water column sampling to ensure minimal resuspension and residual impacts. Following completion of an IR, Alternative 3 would require sediment sampling and consideration of other lines of evidence to confirm that the implementation of the remedy is complete and that it has achieved the RAOs and met other remedial design requirements (e.g., appropriate cap placement).

Sediment sampling would be performed within and outside of the remedial footprint. The framework for confirmation of remedy completion is presented in Appendix H.

Alternative 3 would require long-term monitoring following completion of an IR as part of an adaptive management program to assess system response and recovery and eventually to ensure that the final RGs established in a final ROD have been achieved. Long-term monitoring would be required throughout the 9-mile reach, and would be anticipated to include tissue, water column, and sediment sampling to assess system recovery and progress toward attainment of RGs. It is assumed that long-term monitoring would continue for 30 years after construction is complete. Issuance of a final ROD would replace the monitoring and maintenance requirements of the IR. An initial Adaptive Management Implementation Approach for the upper 9 miles of the LPRSA is presented in Appendix D.

Cap monitoring would be required for Alternative 3 following an IR to assess the performance and stability of the cap. It is anticipated that periodic cap maintenance could be required. Cap monitoring would be performed over the extent of the capped area in Alternative 3, which is assumed to be the same as the remedial footprint of 96 acres. For the IR FS, it is assumed that the Alternative 3 capped area would require maintenance proportional to its volume over the 30-year period. The IR FS cost estimate assumes that 5 percent of the cap would be replaced every 5 years for the first 20 years after construction, and 2.5 percent of the cap would be replaced every 5 years for the following 10 years.

Alternative 3 would rely on institutional controls. Existing institutional controls would be retained until RGs are achieved, at which time there could be revisions to fish consumption advisories. Alternative 3 would require additional controls in perpetuity to protect the integrity of the cap following completion of construction, unless and until some future remedy would address all site risks and allow for the removal of controls.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 would include removal, disposal, and containment to reduce contaminant toxicity and mobility. Contaminants would be treated *ex situ* by stabilization during sediment processing, and *in situ* by the organic carbon content of the cap.

Dredged sediment would be solidified and stabilized via treatment with a reagent admixture (e.g., Portland cement), which would reduce toxicity and mobility before disposal. The reagent would solidify the sediment by reducing the water content to levels appropriate for transportation and disposal at a permitted landfill. Chemical stabilization by the reagent would further immobilize contaminants within the dredged sediment. Solidification and stabilization are considered irreversible, but this component of treatment does not address residuals that would remain in the LPR. An *in situ* sediment volume of 387,000 cy would be solidified and stabilized *ex situ* at a nearby commercial processing facility. Implementation of Alternative 3 would result in the removal of approximately 610 g of 2,3,7,8-TCDD (of the approximate total of

740 g in upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7) and approximately 840 kg of total PCBs (of the approximate total of 1,270 kg in upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7).

The conceptual sediment cap design for Alternative 3 (Appendix F) specifies 5 percent organic carbon content in the sand isolation layer, which would reduce the mobility of residual contaminants in the 96-acre remedial footprint of Alternative 3. Organic carbon in the cap would inhibit potential contaminant movement through the cap and be designed to prevent cap breakthrough within 100 years of placement. Capping is considered to be permanent, and the remaining residuals within the dredge footprint would be covered. Remaining contamination is expected to be effectively sequestered by this treatment action.

ENR and *in situ* sediment treatment options have been retained for consideration in the remedial design, and, if implemented, would sequester contaminants in areas where active dredging and capping are not possible (e.g., utility crossings, bridge abutments, and critical shoreline structures).

Short-Term Effectiveness

Evaluation of short-term effectiveness and impacts of Alternative 3 includes time to achieve RAOs, worker risks and community impacts, resuspension of dredged sediment during implementation, and transport of dredged sediment during implementation.

Time to Achieve RAOs

Alternative 3 is anticipated to achieve the RAOs in 7.6 years following the start of construction. It is anticipated that the IR completion assessment process will take approximately 3 years following the 4.6-year construction period, which includes implementation of post-IR sediment sampling, analysis of results, potential additional sampling to address uncertainty, and the decision-making process following completion of data collection activities.

Worker Risks and Community Impacts

As described above, Alternative 3 includes dredging and capping of 96 acres over an estimated 4.6 years, removing 387,000 cy of contaminated sediment in the upper 9 miles of the LPR. Dredge and cap material would be transported by barge to and from the site. All dredged materials would be disposed offsite. Short-term impacts related to construction duration, footprint size, and removal volume are as follows:

- Potential impacts during operations would occur during a 6-month construction season, July 1 to December 31, each year of construction, with operation 24 hours per day, 6 days per week (see Appendix A for specific assumptions on construction season). As noted in Appendix A, construction is assumed not to occur during an annual winter

shutdown, January 1 to March 1, or during the dredging restriction period associated with the fish migration window, March 1 to June 30.

- Potential short-term worker risks during the construction period include construction hazards from the use of heavy machinery, open water, and exposure to contaminated sediment. A site-specific health and safety plan would be developed to mitigate risks.
- Potential short-term community impacts during the construction period include vehicular delays as a result of bridge closures, road closures, and railroad crossings due to the transportation of dredged sediment and cap material; locally increased traffic as workers access the construction site, which could increase rate of traffic incidents/ accidents; and light pollution, noise, exhaust, and odor from equipment and 24-hour operations. Although these short-term impacts are unlikely due to proposed institutional controls, exposure to the contaminants could occur with river recreation from direct contact, inhalation, or ingestion of surface waters or contaminated sediment.
- During the active construction period, operations would require property for a 5-acre upland support facility to be used for contractor trailers, sample processing, equipment storage, and parking. [73]
- Habitat and ecological disturbance would occur within the remedial footprint and over the construction duration. Implementation of Alternative 3 would include the restoration of disturbed habitat, and restoration activity would likely be implemented following construction. Therefore, there could be short-term ecological effects within the remedial footprint beyond construction duration and prior to completion of restoration activities. BMPs would be applied to minimize disturbances to the ecosystem and wildlife habitats from the dredging and capping activities outside of the remedial footprints. The impacts from dredging and capping would be primarily from sediment disturbances and resuspension, and potentially from increased noise, exhaust, or river traffic. In addition, marsh disturbances could occur as a result of river bank instability. Contractor access to the waterway for land-based dredging and capping could impact the benthic habitat in the shoals.

Resuspension

The implementation of Alternative 3 would result in sediment resuspension and contaminant release into the water column during construction that could result in short-term exposure of humans or biota to increased concentrations of 2,3,7,8-TCDD, total PCBs, and other collocated contaminants. It is anticipated that, during design, the potential for resuspension and release to result in recontamination would be evaluated, and BMPs would be designed and implemented

[73] Identification of potential suitable parcels for the upland support facility would be performed during the early stages of the remedial design.

to reduce or eliminate the negative impacts on source control and achievement of the RAOs (Section 7.1.3).

The model projections for Alternative 3 evaluate dredging scenarios where either 1 or 3 percent of the dredged sediment is released into the water column, and the model does not simulate near-field settling of particles within the vicinity of the dredge or BMPs that would control residual transport. The model projections show that water column concentrations of 2,3,7,8-TCDD and total PCBs would be higher during construction of Alternative 3 compared with the No Action alternative (Figure 8-29), with concentrations varying temporally, driven by both the hydrograph used in the models and the assumed dredge sequence and associated concentrations in the dredged sediment. Most of the highest sediment concentrations in the remedial footprint are located between RM 8.3 and RM 10, and the dredge sequencing used in the models addresses this sediment in the latter 2 years of construction. The model projections also show that, following completion of construction, water column concentrations settle down to a level below pre-construction concentrations.

Downstream and Upstream Transport

The implementation of Alternative 3 would result in increased downstream transport of 2,3,7,8-TCDD and total PCBs at RM 8.3 that could result in short-term exposure of humans or biota to increased concentrations during construction below RM 8.3 (Figures 8-30 and 8-32). Projected water column fluxes in this period are also influenced by the hydrograph that is used in the models, the assumed dredge sequence, as well as the construction in the lower 8 miles. Total water column load at RM 8.3 over the construction period is projected to be approximately 37 to 47 g of 2,3,7,8-TCDD (Figure 8-31), and approximately 129 to 145 kg of total PCBs (Figure 8-33). The implementation of Alternative 3 is not projected to increase transport at RM 0 or RM 15 during construction.

Implementability

Alternative 3 includes dredging of approximately 387,000 cy of sediment, followed by placement of an approximate equivalent volume of capping material. Dredged sediment would be transported to a treatment facility for processing, followed by transport to an offsite disposal facility. The technologies and methods to complete this work are well-established. Necessary equipment (including custom equipment), materials, facilities, and transportation capacity would be available with sufficient lead times.

BMPs would be required during the construction of Alternative 3 to manage dredge residuals and recontamination (Sections 7.1.3 and 8.2.2).

Construction challenges and constraints would be expected to be significant for Alternative 3, given the urban environment of the LPR. Utility crossings, bridge abutments, and critical shoreline structures, discussed in Section 2.3 and Appendix E, could limit or prohibit active

dredging and capping in some areas of the Alternative 3 remedial footprint. Dredge offsets and/or engineering controls may be required to protect shoreline structures. In those areas, ENR and/or *in situ* sediment treatment may be evaluated for implementability and effectiveness during remedial design.

Numerous low bridge crossings and other navigational constraints may necessitate specialty, low-profile vessels to move equipment and materials up and down the river, and frequent bridge openings proportionate to the number of projected barge trips for each alternative, to allow barges and tugs to pass. As evidenced during the RM 10.9 and Phase 1 removal actions (Appendix E), inoperable bridges resulted in construction delays. The need for custom equipment, and more generally the optimal methods for material transport, would be evaluated during remedial design to address these constraints and challenges.

Alternative 3 is anticipated to be administratively feasible; however, coordinating with property owners and local governments and obtaining permit equivalents can be anticipated to be time consuming, given the magnitude of the remedy, with the potential to delay construction.

Alternative 3 would be designed to accommodate future anticipated uses of the upper 9 miles of the LPR, including access by waterfront visitors and in-water recreational users.

The in-water construction for the lower 8-mile remedial action is scheduled to begin mid-2022. It is assumed that Alternative 3 implementation would begin in 2024, and the construction periods of the two actions would overlap by several years. Given the estimated schedule, there would be opportunity in the implementation of Alternative 3 to take advantage of any lessons learned during the lower 8-mile remedial design and initial years of remedial construction. Further, there may be opportunities to use common resources (e.g., sediment processing facilities or specialized equipment). The technical and administrative feasibility of such opportunities would be explored during remedial design.

Cost

The total estimated present value cost of Alternative 3 is $441 million (Table 8-4). Costs include the PDI, remedial design, direct and indirect capital costs, and annual and periodic OMM costs for 30 years after the end of construction. The direct capital, annual OMM, and periodic costs include a 25 percent contingency factor to address scope and bid uncertainty (Section 8.2.5). Costs are presented on a net present value basis using a discount rate of 7 percent. The detailed cost estimate for Alternative 3 is provided in Appendix G.

A cost sensitivity analysis presented in Table 8-5 shows the sensitivity of the total estimated cost to discount rates and contingency assumptions. Costs are presented undiscounted and with a discount rate of 7 percent and 1.5 percent (a reasonable expected discount rate for a 30-year project based on information published by OMB [2018]). Contingency factors of 25 and 35 percent are presented.

8.3.4 Alternative 4: 2,3,7,8-TCDD Target SWAC of 65 ng/kg, Total PCBs RAL of 1 mg/kg

Alternative 4 includes dredging and capping to attain a 2,3,7,8-TCDD target SWAC of 65 ng/kg and meet a total PCBs RAL of 1 mg/kg, as described in Section 7.3.4. The evaluation of this alternative incorporates the Phase 1 removal action, the RM 10.9 time-critical removal action, and the planned lower 8-mile remedial action. In the following sections, Alternative 4 is evaluated against the threshold and primary balancing criteria.

8.3.4.1 Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 4 would achieve the source control goals established in the IR RAOs and would meet the IR FS metric of ability to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations. Remediation of sediment within the remedial footprint for Alternative 4 can be anticipated to achieve the following:

- Attainment of RAO 1, post-IR target SWACs of 85 ng/kg for 2,3,7,8-TCDD and of 0.46 mg/kg for total PCBs (subject to post-construction confirmation upon completion of the IR in accordance with the IR remedy completion framework [Appendix H])
- Removal of sediment with the highest concentrations of 2,3,7,8-TCDD and total PCBs, reducing ongoing potential sources of legacy sediment contamination into the water column and biota
- Reduction of 2,3,7,8-TCDD surface sediment SWAC of approximately 94 percent, from 932 ng/kg[74] to 60 ng/kg and reduction of total PCBs surface sediment SWAC of approximately 84 percent, from 1.5 mg/kg to 0.24 mg/kg (Table 7-2)
- Ongoing recovery of surface sediment concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants following IR completion
- Ongoing recovery of surface water concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants
- Recovery of fish tissue concentrations of 2,3,7,8-TCDD, total PCBs, and other contaminants resulting from reduced concentrations in sediment and the water column
- Reduced potential for human health and the ecosystem exposure to 2,3,7,8-TCDD, total PCBs, and other contaminants resulting from SWAC and water column concentration reductions.

[74] Initial SWACs based on CS 37 mapped to the model grid, see Appendix C.

Compliance with ARARs

Alternative 4 can be designed and implemented to comply with all substantive location- and action-specific ARARs. Alternative 4 could require one or more ARAR waivers during construction to meet threshold criterion of compliance with ARARs.

Alternative 4 is anticipated to comply with the ARARs through appropriate engineering design and agency review processes. Confirmation of ARARs compliance is typically demonstrated during remedial design and through the remedial action work plan (e.g., environmental protection plan, construction quality control plan, waste management plan, transportation and disposal plan, stormwater pollution and spill prevention plan, and BMPs) as well as monitoring during the construction period.

A final remedy for surface water[75] will be established in the final ROD for the entire OU4. While the IR is anticipated to improve water quality, ARARs for water quality may not be achieved following completion (see Section 4.2.1); however, no evaluation of the potential need for a TI waiver was performed as part of the IR FS.

8.3.4.2 Primary Balancing Criteria

Long-Term Effectiveness and Permanence

Evaluation metrics for long-term effectiveness and permanence are source control and recovery potential; cap stability; and monitoring, maintenance, and institutional controls (Table 8-1).

Source Control and Recovery Potential

Implementation of Alternative 4 would achieve source control and result in a high potential for accelerated recovery, as discussed below in the evaluation of Alternative 4 against the source control and recovery potential metrics (Table 8-1). See Section 8.1.4.2 for a discussion of the individual metrics.

Efficacy of RALs based on the CSM

Under the estimated technical specifications for Alternative 4 (Table 7-1), removal and capping of sediment to address RAO 1 and RAO 2 are estimated to achieve a post-construction surface sediment SWAC of 60 ng/kg for 2,3,7,8-TCDD and 0.24 mg/kg for total PCBs (Table 7-2). This is achieved by remediation of surface sediment with concentrations higher than RALs of 164 ng/kg for 2,3,7,8-TCDD and 1 mg/kg for total PCBs, along with additional remediation of areas vulnerable to erosion with concentrations in the 0.5–1.5 ft depth interval that are higher than 2 times the corresponding surface RALs, as described in Appendix B. Implementation of the Alternative 4 RALs would result in removal of sediment that is impeding recovery, based on the evaluation of water column particulate concentrations evaluated in the CSM for natural

[75] The final remedy will also address any remaining site risks in the upper 9 miles.

recovery (Section 2.6). The 2,3,7,8-TCDD RAL under Alternative 4 falls below the estimated 200 to 400 ng/kg concentration range for water column particles depositing on the sediment surface, while the total PCBs RAL of 1 mg/kg reflects the current understanding of water column particulate concentrations for total PCBs. Alternative 4 would thereby effectively address sources of 2,3,7,8-TCDD and total PCBs in surface and subsurface sediment and achieve the source control goals of an IR established under RAO 1 and RAO 2.

Areas, masses, and volumes of source removal

Implementation of Alternative 4, would remove 419,000 cy of sediment from an area of 104 acres within the site (Table 7-1). The estimated mass of contaminants removed in the upper 0.5 ft of the sediment bed (the relevant depth interval for human health and ecological exposure) is approximately 125 g of 2,3,7,8-TCDD (of the approximate total of 133 g in RM 8.3 to RM 15[76]; Table 8-7) and approximately 167 kg of total PCBs (of the approximate total of 197 kg in RM 8.3 to RM 15; Table 8-7).

Distribution of post-IR concentrations relative to pre-IR concentrations

Figures 8-1c and 8-2c compare the mapped surface sediment concentrations prior to and following the implementation of Alternative 4, and Figures 8-3 and 8-4 show the distribution of surface contaminant concentrations pre- and post-implementation for 2,3,7,8-TCDD and total PCBs, respectively. These figures show that the highest concentrations of 2,3,7,8-TCDD and total PCBs would be removed throughout the upper 9 miles and that the distribution of concentrations of 2,3,7,8-TCDD and total PCBs would shift towards lower values.

Model projections of average sediment concentrations and recovery half-life

In the 10 years following completion of an IR, implementation of Alternative 4 is projected to result in a significant reduction in projected sediment SWACs of 2,3,7,8-TCDD and total PCBs in the upper 9 miles (RM 8.3 to RM 15), compared with SWAC at model initiation (i.e., before implementation of the lower 8-mile remedial action and the upper 9-mile source control IR; Figures 8-6 and 8-7, panel a). In year 10 following IR completion (model year 18), the SWACs are considerably lower than the No Action alternative (Figures 8-6 and 8-7, panel b; Table 8-8).

Implementation of Alternative 4, together with the lower 8-mile remedy, is projected to result in significant SWAC reductions overall in the LPR. In the lower 8 miles (RM 0 to RM 8.3), Alternative 4 post-IR sediment SWACs of 2,3,7,8-TCDD and total PCBs are lower than the lower 8-mile SWACs at model initiation (i.e., pre-IR SWAC, Figures 8-8 and 8-9, panel a). River-wide (RM 0 to RM 15), implementation of Alternative 4 is projected to provide additional reduction in SWACs compared with implementation of the lower 8-mile remedy alone (Alternative 1) (Figures 8-10 and 8-11, panels a,b; Table 8-8). While reductions in sediment concentrations in

[76] The estimated mass removed for each alternative and mass in RM 8.3 to RM 15 is based on the 2010 mapping interpolations described in Appendix J of the RI report (Anchor QEA 2019). An average bulk density of 0.848 g/cm^3 was used for each of the CS 37 node concentrations.

the lower 8 miles are primarily influenced by the implementation of the lower 8-mile remedial action, model projections suggest a longer-term benefit to lower-8-mile SWAC reduction at the end of the 10-year period (model year 18) from source control implementation in the upper 9 miles (Figures 8-8 and 8-9, panel b; Table 8-8).

The projected SWAC reductions resulting from the implementation of Alternative 4 in the upper 9 miles and river-wide result from the removal of high concentrations of 2,3,7,8-TCDD and total PCBs in sediment to control sources. The control of sources would accelerate the recovery of the water column and unremediated sediment.

The estimated recovery half-life of the projected sediment SWACs (i.e., the time to reduce the initial post-IR SWAC by 50 percent[77]) is presented in Figure 8-12. The 2,3,7,8-TCDD SWAC half-life ranges from approximately 7 to 13 years (Table 8-8), compared with the recovery half-life of No Action alternative of approximately 125 to 244 years (where a lower number means faster recovery of the sediment SWACs). The total PCB SWAC recovery half-life ranges from approximately 18 to 43 years, compared with the recovery half-life of the No Action alternative of approximately 79 to 110 years. The significant reduction in projected half-life under Alternative 4 confirms the effectiveness of an IR to achieve source control and promote accelerated recovery.

Model projections of average water column concentrations

Projected water column concentrations of 2,3,7,8-TCDD and total PCBs fluctuate in the 10-year period following completion of Alternative 4 (Figures 8-13 and 8-14, panel a); these fluctuations are clearly tied to the modeled hydrograph (Figure 8-5), as they are evident in all alternatives, including the No Action alternative. Averaged over the 10-year post-IR period, 2,3,7,8-TCDD water column concentrations under Alternative 4 are approximately 20 to 25 percent of the water column concentrations under the No Action alternative (Figure 8-13, panel b; Table 8-8). The 10-year post-IR average water column concentration of total PCBs under Alternative 4 shows a smaller, but discernible, reduction relative to the No Action alternative, due to the influence of background concentrations entering the LPR at Dundee Dam and from tributaries (Figure 8-14, panel b; Table 8-8). The reduction in water column concentrations results from the control of sediment sources, and will subsequently result in recovery of unremediated sediment.

Model projections of average and cumulative water column loads

Over the 10 years following completion of an IR, the implementation of Alternative 4 would result in a reduction of net water column contaminant load moving out of the upper 9 miles (at RM 8.3) of the LPR, as shown by model projections of 2,3,7,8-TCDD and total PCBs annual

[77] The recovery half-life is calculated relative to the alternative-specific SWAC at the end of model year 8; the SWAC achieved after one half-life is therefore much lower for Alternative 4 than for Alternative 1. See Appendix C for a discussion of the half-life calculation.

water column load at RM 8.3 (Figures 8-16 and 8-20, panels a,b; Table 8-8) and RM 0 (Figures 8-17 and 8-21, panels a,b). Projected loads fluctuate over time, corresponding to the peak flows seen in the hydrograph used in the projections (Figure 8-5). Over the 10 years following completion of an IR, the projected total water column load leaving the upper 9 miles is approximately 6.1 to 8.5 g of 2,3,7,8-TCDD and approximately 134 to 139 kg of total PCBs (Figures 8-18 and 8-22, panel b; Table 8-8). The implementation of Alternative 4 is not projected to materially affect net downstream water column loads at RM 15 (Figures 8-15 and 8-19). The reduction in water column loads results from the control of sediment sources and associated reduction in water column concentrations.

Model projections of average net and gross contaminant erosional flux

Projected sediment contaminant erosional fluxes fluctuate over the 10-year post-IR period (Figures 8-23 to 8-26, panel a). Projected fluctuations are tied to the hydrograph (Figure 8-5) and projected total PCB erosional fluxes are influenced by background concentrations. The erosional fluxes averaged over the 10-year post IR period are lower for Alternative 4 compared with the No Action alternative (Figures 8-23 to 8-26, panel b; Table 8-8), indicating a reduction of contaminant mass entering the water column, which would reduce the redistribution of contaminants within the RM 8.3 to RM 15 reach and reduce contaminant mass moving downstream (as evidenced in the reduction of water column load). The similar reductions in gross and net erosional 2,3,7,8-TCDD flux indicate that the removal of sediment under Alternative 4 removes the dominant sources of 2,3,7,8-TCDD (i.e., addressing sources reduces erosional flux which in turn reduces depositional flux). For total PCBs, the reduction in net flux under Alternative 4 is greater than the reduction in gross flux compared with the No Action alternative. Addressing source areas reduces erosion within the IR reach, but due to ongoing sources of total PCBs originating upstream of the LPRSA, depositional flux is not reduced to the same extent, which causes the gross erosion from sediment in the RM 8.3 to RM 15 reach to continue at levels that are closer to Alternative 1 for total PCBs than for 2,3,7,8-TCDD. The reduction in the magnitude of contaminant erosional loadings to the water column within the IR reach will result in ongoing recovery of the water column and sediment.

Model projections of contaminant concentrations on depositing fine sediment

Model projections of annual average concentrations of 2,3,7,8-TCDD on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 4 are roughly constant (Figure 8-27, panel a), with the exception of the first two years (model years 9 and 10), which likely indicates that the system is still responding to the dredging. Model projections of annual average concentrations of total PCBs on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 4 show some decline following the first two years (Figure 8-28, panel a). The average projected concentration of 2,3,7,8-TCDD on depositing fine sediment over the 10-year post-IR period ranges from 23 to 28 ng/kg, compared with 111 to 117 ng/kg for the No Action alternative (Figures 8-27 and 8-28, panel b; Table 8-8). The average projected concentration of total PCBs on depositing fine

sediment over the 10-year post-IR period ranges from 0.43 to 0.45 mg/kg, compared with approximately 0.54 mg/kg under the No Action alternative (Figure 8-28, panel b; Table 8-8). The projected reduction in concentration on depositing fines is consistent with the CSM: that removal of source sediment under Alternative 4 will reduce concentrations on depositing fines and thereby accelerate recovery of unremediated sediment.

Cap Stability

Alternative 4 includes capping throughout the remedial footprint, to a thickness equal to the depth of sediment removal (2 ft dredge depth plus 0.5 ft overdredge). The conceptual cap design (Appendix F) includes an isolation layer consisting of sand amended with activated carbon, an armor layer to resist up to a 100-year-flood event, and a surface layer of habitat substrate in the shoals. Based on subsurface sediment parameters, predicted contaminant breakthrough of the cap would not occur within 100 years. The conceptual cap evaluation demonstrates that a stable cap capable of providing long-term protectiveness can be implemented to isolate contaminated sediment left in place following implementation of an IR.

Monitoring, Maintenance, and Institutional Controls

During implementation of an IR, Alternative 4 would require construction monitoring to verify horizontal and vertical sediment cut lines, sediment sampling to evaluate the efficacy of residual management measures, bathymetry surveys to verify proper cap placement, and water column sampling to ensure minimal resuspension and residual impacts. Following completion of an IR, Alternative 4 would require sediment sampling and consideration of other lines of evidence to confirm that the implementation of the remedy is complete and that it has achieved the RAOs and met other remedial design requirements (e.g., appropriate cap placement). Sediment sampling would be performed within and outside of the remedial footprint. The framework for confirmation of remedy completion is presented in Appendix H.

Alternative 4 would require long-term monitoring following completion of an IR as part of an adaptive management program to assess system response and recovery and eventually to ensure that the final RGs established in a final ROD have been achieved. Long-term monitoring would be required throughout the 9-mile reach, and would be anticipated to include tissue, water column, and sediment sampling to assess system recovery and progress toward attainment of RGs. It is assumed that long-term monitoring would continue for 30 years after construction is complete. Issuance of a final ROD would replace the monitoring and maintenance requirements of the IR. An initial Adaptive Management Implementation Approach for the upper 9 miles of the LPRSA is presented in Appendix D.

Cap monitoring would be required for Alternative 4 following an IR to assess the performance and stability of the cap. It is anticipated that periodic cap maintenance could be required. Cap monitoring would be performed over the extent of the capped area in Alternative 4, which is

assumed to be the same as the remedial footprint of 104 acres. For the IR FS, it is assumed that the Alternative 4 capped area would require maintenance proportional to its volume over the 30-year period. The IR FS cost estimate assumes that 5 percent of the cap would be replaced every 5 years for the first 20 years after construction, and 2.5 percent of the cap would be replaced every 5 years for the following 10 years.

Alternative 4 would rely on institutional controls. Existing institutional controls would be retained until RGs are achieved, at which time there could be revisions to fish consumption advisories. Alternative 4 would require additional controls in perpetuity to protect the integrity of the cap following completion of construction, unless and until some future remedy would address all site risks and allow for the removal of controls.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 would include removal, disposal, and containment to reduce contaminant toxicity and mobility. Contaminants would be treated *ex situ* by stabilization during sediment processing, and *in situ* by the organic carbon content of the cap.

Dredged sediment would be solidified and stabilized via treatment with a reagent admixture (e.g., Portland cement), which would reduce toxicity and mobility before disposal. The reagent would solidify the sediment by reducing the water content to levels appropriate for transportation and disposal at a permitted landfill. Chemical stabilization by the reagent would further immobilize contaminants within the dredged sediment. Solidification and stabilization are considered irreversible, but this component of treatment does not address residuals that would remain in the LPR. An *in situ* sediment volume of 419,000 cy would be solidified and stabilized *ex situ* at a nearby commercial processing facility. Implementation of Alternative 4 would result in removal of approximately 630 g of 2,3,7,8-TCDD (of the approximate total of 740 g in upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7) and approximately 860 kg of total PCBs (of the approximate total of 1,270 kg in upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7).

The conceptual sediment cap design for Alternative 4 (Appendix F) specifies 5 percent organic carbon content in the sand isolation layer, which would reduce the mobility of residual contaminants in the 104-acre remedial footprint of Alternative 4. Organic carbon in the cap would inhibit potential contaminant movement through the cap and be designed to prevent cap breakthrough within 100 years of placement. Capping is considered to be permanent, and the remaining residuals within the dredge footprint would be covered. Remaining contamination is expected to be effectively sequestered by this treatment action.

ENR and *in situ* sediment treatment options have been retained for consideration in the remedial design, and, if implemented, would sequester contaminants in areas where active dredging and capping are not possible (e.g., utility crossings, bridge abutments, and critical shoreline structures).

Short-Term Effectiveness

Evaluation of short-term effectiveness and impacts of Alternative 4 includes time to achieve RAOs, worker risks and community impacts, resuspension of dredged sediment during implementation, and transport of dredged sediment during implementation.

Time to Achieve RAOs

Alternative 4 is anticipated to achieve the RAOs in 7.9 years following the start of construction. It is anticipated that the IR completion assessment process will take approximately 3 years following the 4.9-year construction period, which includes implementation of post-IR sediment sampling, analysis of results, potential additional sampling to address uncertainty, and the decision-making process following completion of data collection activities.

Worker Risks and Community Impacts

As described above, Alternative 4 includes dredging and capping of 104 acres over an estimated 4.9 years, removing 419,000 cy of contaminated sediment in the upper 9 miles of the LPR. Dredge and cap material would be transported by barge to and from the site. All dredged materials would be disposed offsite. Short-term impacts related to construction duration, footprint size, and removal volume are as follows:

- Potential impacts during operations would occur during a 6-month construction season, July 1 to December 31, each year of construction, with operation 24 hours per day, 6 days per week (see Appendix A for specific assumptions on construction season). As noted in Appendix A, construction is assumed not to occur during an annual winter shutdown, January 1 to March 1, or during the dredging restriction period associated with the fish migration window, March 1 to June 30.
- Potential short-term worker risks during the construction period include construction hazards from the use of heavy machinery, open water, and exposure to contaminated sediment. A site-specific health and safety plan would be developed to mitigate risks.
- Potential short-term community impacts during the construction period include vehicular delays as a result of bridge closures, road closures, and railroad crossings due to the transportation of dredged sediment and cap material; locally increased traffic as workers access the construction site, which could increase rate of traffic incidents/ accidents; and light pollution, noise, exhaust, and odor from equipment and 24-hour operations. Although these short-term impacts are unlikely due to proposed institutional controls, exposure to the contaminants could occur with river recreation from direct contact, inhalation, or ingestion of surface waters or contaminated sediment.

- During the active construction period, operations would require property for a 5-acre upland support facility to be used for contractor trailers, sample processing, equipment storage, and parking. [78]
- Habitat and ecological disturbance would occur within the remedial footprint and over the construction duration. Implementation of Alternative 4 would include the restoration of disturbed habitat, and restoration activity would likely be implemented following construction. Therefore, there could be short-term ecological effects within the remedial footprint beyond construction duration and prior to completion of restoration activities. BMPs would be applied to minimize disturbances to the ecosystem and wildlife habitats from the dredging and capping activities outside of the remedial footprints. The impacts from dredging and capping would be primarily from sediment disturbances and resuspension, and potentially from increased noise, exhaust, or river traffic. In addition, marsh disturbances could occur as a result of river bank instability. Contractor access to the waterway for land-based dredging and capping could impact the benthic habitat in the shoals.

Resuspension

The implementation of Alternative 4 would result in sediment resuspension and contaminant release into the water column during construction that could result in short-term exposure of humans or biota to increased concentrations of 2,3,7,8-TCDD, total PCBs, and other collocated contaminants. It is anticipated that, during design, the potential for resuspension and release to result in recontamination would be evaluated, and BMPs would be designed and implemented to reduce or eliminate the negative impacts on source control and achievement of the RAOs (Section 7.1.3).

The model projections for Alternative 4 evaluate dredging scenarios where either 1 or 3 percent of the dredged sediment is released into the water column, and the model does not simulate near-field settling of particles within the vicinity of the dredge or BMPs that would control residual transport. The model projections show that water column concentrations of 2,3,7,8-TCDD and total PCBs would be higher during construction of Alternative 4 compared with the No Action alternative (Figure 8-29), with concentrations varying temporally, driven by both the hydrograph used in the models and the assumed dredge sequence and associated concentrations in the dredged sediment. Most of the highest sediment concentrations in the remedial footprint are located between RM 8.3 and RM 10, and the dredge sequencing used in the models addresses this sediment in the latter 2 years of construction. The model projections also show that, following completion of construction, water column concentrations settle down to a level below pre-construction concentrations.

[78] Identification of potential suitable parcels for the upland support facility would be performed during the early stages of the remedial design.

Downstream and Upstream Transport

The implementation of Alternative 4 would result in increased downstream transport of 2,3,7,8-TCDD and total PCBs at RM 8.3 that could result in short-term exposure of humans or biota to increased concentrations during construction below RM 8.3 (Figures 8-30 and 8-32). Projected water column fluxes in this period are also influenced by the hydrograph that is used in the models, the assumed dredge sequence, as well as the construction in the lower 8 miles. Total water column load at RM 8.3 over the construction period is projected to be approximately 38 to 48 g of 2,3,7,8-TCDD (Figure 8-31), and approximately 130 to 147 kg of total PCBs (Figure 8-33). The implementation of Alternative 4 is not projected to increase transport at RM 0 or RM 15 during construction.

Implementability

Alternative 4 includes dredging of approximately 419,000 cy of sediment, followed by placement of an approximate equivalent volume of capping material. Dredged sediment would be transported to a treatment facility for processing, followed by transport to an offsite disposal facility. The technologies and methods to complete this work are well-established. Necessary equipment (including custom equipment), materials, facilities, and transportation capacity would be available with sufficient lead times.

BMPs would be required during the construction of Alternative 4 to manage dredge residuals and recontamination (Sections 7.1.3 and 8.2.2).

Construction challenges and constraints would be expected to be significant for Alternative 4, given the urban environment of the LPR. Utility crossings, bridge abutments, and critical shoreline structures, discussed in Section 2.3 and Appendix E, could limit or prohibit active dredging and capping in some areas of the Alternative 4 remedial footprint. Dredge offsets and/or engineering controls may be required to protect shoreline structures. In those areas, ENR and/or *in situ* sediment treatment may be evaluated for implementability and effectiveness during remedial design.

Numerous low bridge crossings and other navigational constraints may necessitate specialty, low-profile vessels to move equipment and materials up and down the river, and frequent bridge openings proportionate to the number of projected barge trips for each alternative, to allow barges and tugs to pass. As evidenced during the RM 10.9 and Phase 1 removal actions (Appendix E), inoperable bridges resulted in construction delays. The need for custom equipment, and more generally the optimal methods for material transport, would be evaluated during remedial design to address these constraints and challenges.

Alternative 4 is anticipated to be administratively feasible; however, coordinating with property owners and local governments and obtaining permit equivalents can be anticipated to be time consuming, given the magnitude of the remedy, with the potential to delay construction.

Alternative 4 would be designed to accommodate future anticipated uses of the upper 9 miles of the LPR, including access by waterfront visitors and in-water recreational users.

The in-water construction for the lower 8-mile remedial action is scheduled to begin mid-2022. It is assumed that Alternative 4 implementation would begin in 2024, and the construction periods of the two actions would overlap by several years. Given the estimated schedule, there would be opportunity in the implementation of Alternative 4 to take advantage of any lessons learned during the lower 8-mile remedial design and initial years of remedial construction. Further, there may be opportunities to use common resources (e.g., sediment processing facilities or specialized equipment). The technical and administrative feasibility of such opportunities would be explored during remedial design.

Cost

The total estimated present value cost of Alternative 4 is $468 million (Table 8-4). Costs include the PDI, remedial design, direct and indirect capital costs, and annual and periodic OMM costs for 30 years after the end of construction. The direct capital, annual OMM, and periodic costs include a 25 percent contingency factor to address scope and bid uncertainty (Section 8.2.5). Costs are presented on a net present value basis using a discount rate of 7 percent. The detailed cost estimate for Alternative 4 is provided in Appendix G.

A cost sensitivity analysis presented in Table 8-5 shows the sensitivity of the total estimated cost to discount rates and contingency assumptions. Costs are presented undiscounted and with a discount rate of 7 percent and 1.5 percent (a reasonable expected discount rate for a 30-year project based on information published by the OMB [2018]). Contingency factors of 25 and 35 percent are presented.

8.3.5 Alternative 5: 2,3,7,8-TCDD Target SWAC of 125 ng/kg

Alternative 5 includes dredging and capping to attain a 2,3,7,8-TCDD target SWAC of 125 ng/kg, as described in Section 7.3.5. Alternative 5, which does not achieve the RAOs (i.e., does not achieve the target 2,3,7,8-TCDD SWAC of 85 ng/kg upon completion, and does not directly consider total PCBs), is included to compare a smaller remedy defined only on the basis of a 2,3,7,8-TCDD SWAC target of 125 ng/kg with the other alternatives. Alternative 5 also includes additional dredging and capping in areas with erosional potential and high subsurface sediment concentrations (0.5–1.5 ft) to address RAO 2. The evaluation of this alternative incorporates the Phase 1 removal action, the RM 10.9 time-critical removal action, and the planned lower 8-mile remedial action. In the following sections, Alternative 5 is evaluated against the threshold and primary balancing criteria. Although this alternative does not meet RAO 1, it has been evaluated for comparison with the other alternatives.

8.3.5.1 Threshold Criteria

Overall Protection of Human Health and the Environment

Alternative 5 would have the ability to meet the IR FS metric of ability to progress towards overall protection of human health and the environment by removal of the highest concentrations of source material (i.e., 2,3,7,8-TCDD concentrations greater than or equal to the Alternative 5 RAL of 346 ng/kg). However, Alternative 5 would not achieve RAO 1, a post-IR 2,3,7,8-TCDD SWAC of 85 ng/kg and a post-IR total PCBs SWAC of 0.46 mg/kg, following completion of construction.

Compliance with ARARs

Alternative 5 can be designed and implemented to comply with all substantive location- and action-specific ARARs. Alternative 5 could require one or more ARAR waivers during construction to meet the threshold criterion of compliance with ARARs.

Alternative 5 is anticipated to comply with the ARARs through appropriate engineering design and agency review processes. Confirmation of ARARs compliance is typically demonstrated during remedial design and through the remedial action work plan (e.g., environmental protection plan, construction quality control plan, waste management plan, transportation and disposal plan, stormwater pollution and spill prevention plan, and BMPs) as well as monitoring during the construction period.

A final remedy for surface water[79] will be established in the final ROD for the LPRSA. While the IR is anticipated to improve water quality, ARARs for water quality may not be achieved following completion (see Section 4.2.1); however, no evaluation of the potential need for a TI waiver was performed as part of the IR FS.

8.3.5.2 Primary Balancing Criteria

Although Alternative 5 does not satisfy the threshold criteria because it fails to achieve the RAOs, it was retained for evaluation of the balancing criteria for comparison with the other active alternatives.

Long-Term Effectiveness and Permanence

Evaluation metrics for long-term effectiveness and permanence are source control and recovery; cap stability; and monitoring, maintenance, and institutional controls (Table 8-1).

[79] The final remedy will also address any remaining site risks in the upper 9 miles.

Source Control and Recovery Potential

Implementation of Alternative 5 would achieve some source control and result in a high potential for accelerated recovery, as discussed below in the evaluation of Alternative 5 against the source control and recovery potential metrics (Table 8-1). See Section 8.1.4.2 for a discussion of the individual metrics. The removal of sediment with 2,3,7,8-TCDD above 346 ng/kg would provide some source control, but sediment with concentrations above the target concentrations would remain that could inhibit recovery. Although high concentrations of total PCBs would be removed where they are collocated with 2,3,7,8-TCDD, total PCBs are not targeted by Alternative 5.

Efficacy of RALs based on the CSM

Under the estimated technical specifications for Alternative 5 (Table 7-1), removal and capping of sediment to address RAO 1 and RAO 2 are estimated to achieve a post-construction surface sediment SWAC of 121 ng/kg for 2,3,7,8-TCDD and 0.49 mg/kg for total PCBs (Table 7-2). This is achieved by remediation of surface sediment with concentrations higher than RALs of 346 ng/kg for 2,3,7,8-TCDD, along with additional remediation of areas vulnerable to erosion with concentrations in the 0.5–1.5 ft depth interval that are higher than 2 times the corresponding surface RAL, as described in Appendix B. Implementation of the Alternative 5 RALs would result in removal of sediment that is impeding recovery, based on the evaluation of water column particulate concentrations evaluated in the CSM for natural recovery (Section 2.6). The 2,3,7,8-TCDD RAL under Alternative 5 falls in the upper third of the estimated 200 to 400 ng/kg concentration range for water column particles depositing on the sediment surface. Alternative 5 would thereby address sources of 2,3,7,8-TCDD in surface and subsurface sediment and achieve some of the source control goals of an IR established under RAO 1 and RAO 2.

Areas, masses, and volumes of source removal

Implementation of Alternative 5 would remove 250,000 cy of sediment from an area of 62 acres within the site (Table 7-1). The estimated mass of contaminants removed in the upper 0.5 ft of the sediment bed (the relevant depth interval for human health and ecological exposure) is approximately 117 g of 2,3,7,8-TCDD (of the approximate total of 133 g in RM 8.3 to RM 15[80]; Table 8-7) and approximately 135 kg of total PCBs (of the approximate total of 197 kg in RM 8.3 to RM 15; Table 8-7).

Distribution of post-IR concentrations relative to pre-IR concentrations

Figures 8-1d and 8-2d compare the mapped surface sediment concentrations prior to and following the implementation of Alternative 5, and Figures 8-3 and 8-4 show the distribution of

[80] The estimated mass removed for each alternative and mass in RM 8.3 to RM 15 is based on the 2010 mapping interpolations described in Appendix J of the RI report (AQEA 2019). An average bulk density of 0.848 g/cm^3 was used for each of the CS 37 node concentrations.

surface contaminant concentration pre- and post-implementation for 2,3,7,8-TCDD and total PCBs, respectively. These figures show that the highest concentrations of 2,3,7,8-TCDD and total PCBs would be removed throughout the upper 9 miles and that the distribution of concentrations of 2,3,7,8-TCDD and total PCBs would shift towards lower values.

Model projections of average sediment concentrations and recovery half-life

In the 10 years following completion of an IR, implementation of Alternative 5 is projected to result in a significant reduction in projected sediment SWACs of 2,3,7,8-TCDD and total PCBs in the upper 9 miles (RM 8.3 to RM 15), compared with the SWAC at model initiation (i.e., before implementation of the lower 8-mile remedial action and the upper 9-mile source control IR; Figures 8-6 and 8-7, panel a). In year 10 following IR completion (model year 18), the SWACs are considerably lower than the No Action alternative (Figures 8-6 and 8-7, panel b; Table 8-8).

Implementation of Alternative 5, together with the lower 8-mile remedy, is projected to result in significant SWAC reductions overall in the LPR. In the lower 8 miles (RM 0 to RM 8.3), Alternative 5 post-IR sediment SWACs of 2,3,7,8-TCDD and total PCBs are lower than the lower 8-mile SWACs at model initiation (i.e., pre-IR SWAC; Figures 8-8 and 8-9, panel a). River-wide (RM 0 to RM 15), implementation of Alternative 5 is projected to provide additional reduction in SWACs compared with implementation of the lower 8-mile remedy alone (Alternative 1) (Figures 8-10 and 8-11, panels a,b; Table 8-8). While reductions in sediment concentrations in the lower 8 miles are primarily influenced by the implementation of the lower 8-mile remedial action, model projections suggest a longer-term benefit to lower-8-mile SWAC reduction at the end of the 10-year period (model year 18) from source control implementation in the upper 9 miles (Figures 8-8 and 8-9, panel b; Table 8-8).

The projected SWAC reductions resulting from the implementation of Alternative 5 in the upper 9 miles and river-wide result from the removal of high concentrations of 2,3,7,8-TCDD and total PCBs in sediment to control sources. The control of sources would accelerate the recovery of the water column and unremediated sediment.

The estimated recovery half-life of the projected sediment SWACs (i.e., the time to reduce the initial post-remedy SWAC by 50 percent[81]) is presented in Figure 8-12. The 2,3,7,8-TCDD SWAC half-life ranges from approximately 15 to 65 years (Table 8-8), compared with the recovery half-life of the No Action alternative of approximately 125 to 244 years (where a lower number means faster recovery of the sediment SWACs). The total PCB SWAC recovery half-life ranges from approximately 36 to 71 years, compared with the recovery half-life of the No Action alternative of approximately 79 to 110 years. The significant reduction in projected half-

[81] The recovery half-life is calculated relative to the alternative-specific SWAC at the end of model year 8; the SWAC achieved after one half-life is therefore much lower for Alternative 5 than for Alternative 1. See Appendix C for a discussion of the half-life calculation.

life under Alternative 5 confirms the effectiveness of an IR to achieve some source control and promote accelerated recovery.

Model projections of average water column concentrations

Projected water column concentrations of 2,3,7,8-TCDD and total PCBs fluctuate in the 10-year period following completion of Alternative 5 (Figures 8-13 and 8-14, panel a); these fluctuations are clearly tied to the modeled hydrograph (Figure 8-5), as they are evident in all alternatives, including the No Action alternative. Averaged over the 10-year post-IR period, 2,3,7,8-TCDD water column concentrations under Alternative 5 are approximately 25 to 27 percent of the water column concentrations under the No Action alternative (Figure 8-13, panel b; Table 8-8). The 10-year post-IR average water column concentration of total PCBs under Alternative 5 shows a smaller, but discernible, reduction relative to the No Action alternative, due to the influence of background concentrations entering the LPR at Dundee Dam and from tributaries (Figure 8-14, panel b; Table 8-8). The reduction in water column concentrations results from the control of sediment sources, and will subsequently result in recovery of unremediated sediment.

Model projections of average and cumulative water column loads

Over the 10 years following completion of an IR, the implementation of Alternative 5 would result in a reduction of net water column contaminant load moving out of the upper 9 miles (at RM 8.3) of the LPR, as shown by model projections of 2,3,7,8-TCDD and total PCBs annual water column load at RM 8.3 (Figure 8-16, 8-20, panels a,b; Table 8-8) and RM 0 (Figures 8-17 and 8-21, panels a,b). Projected loads fluctuate over time, corresponding to the peak flows seen in the hydrograph used in the projections (Figure 8-5). Over the 10 years following completion of an IR (model year 18), the projected reduction of cumulative water column load leaving the upper 9 miles (at RM 8.3) is approximately 8.0 to 9.1 g of 2,3,7,8-TCDD and approximately 145 to 148 kg of total PCBs (Figures 8-18 and 8-22, panel b; Table 8-8). The implementation of Alternative 5 is not projected to materially affect net downstream water column loads at RM 15 (Figures 8-15 and 8-19). The reduction in water column loads results from the control of sediment sources and associated reduction in water column concentrations.

Model projections of average net and gross contaminant erosional flux

Projected sediment contaminant erosional fluxes fluctuate over the 10-year post-IR period (Figures 8-23 to 8-26, panel a). Projected fluctuations are tied to the hydrograph (Figure 8-5) and projected total PCB erosional fluxes are influenced by background concentrations. The erosional fluxes averaged over the 10-year post IR period are lower for Alternative 5 compared with the No Action alternative (Figures 8-23 to 8-26, panel b; Table 8-8), indicating a reduction of contaminant mass entering the water column, which would reduce the redistribution of contaminants within the RM 8.3 to RM 15 reach and reduce contaminant mass moving downstream (as evidenced in the reduction of water column load). The similar reductions in gross and net erosional 2,3,7,8-TCDD flux indicate that the removal of sediment under

Alternative 5 removes the dominant sources of 2,3,7,8-TCDD (i.e., addressing sources reduces erosional flux which in turn reduces depositional flux). For total PCBs, the reduction in net flux under Alternative 5 is greater than the reduction in gross flux compared with the No Action alternative. Addressing source areas reduces erosion within the IR reach, but due to ongoing sources of total PCBs originating upstream of the LPRSA, depositional flux is not reduced to the same extent, which causes the gross erosion from sediment in the RM 8.3 to 15 reach to continue at levels that are closer to Alternative 1 for total PCBs than for 2,3,7,8-TCDD. The reduction in the magnitude of contaminant erosional loadings to the water column within the IR reach will result in ongoing recovery of the water column and sediment.

Model projections of contaminant concentrations on depositing fine sediment

Model projections of annual average concentrations of 2,3,7,8-TCDD on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 5 are roughly constant (Figure 8-27, panel a), with the exception of the first two years (model years 9 and 10), which likely indicates that the system is still responding to the dredging. Model projections of annual average concentrations of total PCBs on fine sediment depositing on the sediment bed in the 10-year period following completion of Alternative 5 show some decline following the first two years (Figure 8-28, panel a). The average projected concentration of 2,3,7,8-TCDD on depositing fine sediment over the 10-year post-IR period ranges from 28 to 31 ng/kg, compared with 111 to 117 ng/kg for the No Action alternative (Figures 8-27 and 8-28, panel b; Table 8-8). The average projected concentration of total PCBs on depositing fine sediment over the 10-year post-IR period ranges from 0.45 to 0.46 mg/kg, compared with approximately 0.54 mg/kg under the No Action alternative (Figure 8-28, panel b; Table 8-8). The projected reduction in concentration on depositing fines is consistent with the CSM: that removal of source sediment under Alternative 5 will reduce concentrations on depositing fines and thereby accelerate recovery of unremediated sediment.

Cap Stability

Alternative 5 includes capping throughout the remedial footprint, to a thickness equal to the depth of sediment removal (2 ft dredge depth plus 0.5 ft overdredge). The conceptual cap design (Appendix F) includes an isolation layer consisting of sand amended with activated carbon, an armor layer to resist up to a 100-year-flood event, and a surface layer of habitat substrate in the shoals. Based on subsurface sediment parameters, predicted contaminant breakthrough of the cap would not occur within 100 years. The conceptual cap evaluation demonstrates that a stable cap capable of providing long-term protectiveness can be implemented to isolate contaminated sediment left in place following implementation of an IR.

Monitoring, Maintenance, and Institutional Controls

During implementation of an IR, Alternative 5 would require construction monitoring to verify horizontal and vertical sediment cut lines, sediment sampling to evaluate the efficacy of

residual management measures, bathymetry surveys to verify proper cap placement, and water column sampling to ensure minimal resuspension and residual impacts. Following completion of an IR, Alternative 5 would require sediment sampling and consideration of other lines of evidence to confirm that the implementation of the remedy is complete and that it has achieved the RAOs and met other remedial design requirements (e.g., appropriate cap placement). Sediment sampling would be performed within and outside of the remedial footprint. The framework for confirmation of remedy completion is presented in Appendix H.

Alternative 5 would require long-term monitoring following completion of an IR as part of an adaptive management program to assess system response and recovery and eventually to ensure that the final RGs established in a final ROD have been achieved. Long-term monitoring would be required throughout the 9-mile reach, and would be anticipated to include tissue, water column, and sediment sampling to assess system recovery and progress toward attainment of RGs. It is assumed that long-term monitoring would continue for 30 years after construction is complete. Issuance of a final ROD would replace the monitoring and maintenance requirements of the IR. An initial Adaptive Management Implementation Approach for the upper 9 miles of the LPRSA is presented in Appendix D.

Cap monitoring would be required for Alternative 5 following an IR to assess the performance and stability of the cap. It is anticipated that periodic cap maintenance could be required. Cap monitoring would be performed over the extent of the capped area in Alternative 5, which is assumed to be the same as the remedial footprint of 62 acres. For the IR FS, it is assumed that the Alternative 5 capped area would require maintenance proportional to its volume over the 30-year period. The IR FS cost estimate assumes that 5 percent of the cap would be replaced every 5 years for the first 20 years after construction, and 2.5 percent of the cap would be replaced every 5 years for the following 10 years.

Alternative 5 would rely on institutional controls. Existing institutional controls would be retained until RGs are achieved, at which time there could be revisions to fish consumption advisories. Alternative 5 would require additional controls in perpetuity to protect the integrity of the cap following completion of construction, unless and until some future remedy would address all site risks and allow for the removal of controls.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 5 would include removal, disposal, and containment to reduce contaminant toxicity and mobility. Contaminants would be treated *ex situ* by stabilization during sediment processing, and *in situ* by the organic carbon content of the cap.

Dredged sediment would be solidified and stabilized via treatment with a reagent admixture (e.g., Portland cement), which would reduce toxicity and mobility before disposal. The reagent would solidify the sediment by reducing the water content to levels appropriate for transportation and disposal at a permitted landfill. Chemical stabilization by the reagent would

further immobilize contaminants within the dredged sediment. Solidification and stabilization are considered irreversible, but this component of treatment does not address residuals that would remain in the LPR. An *in situ* sediment volume of 250,000 cy would be solidified and stabilized *ex situ* at a nearby commercial processing facility. Implementation of Alternative 5 would result in removal of approximately 530 g of 2,3,7,8-TCDD (of the approximate total of 740 g in the upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7) and approximately 630 kg of total PCBs (of the approximate total of 1,270 kg in the upper 2.5 ft of the sediment bed in RM 8.3 to RM 15; Table 8-7).

The conceptual sediment cap design for Alternative 5 (Appendix F) specifies 5 percent organic carbon content in the sand isolation layer, which would reduce the mobility of residual contaminants in the 62-acre remedial footprint of Alternative 5. Organic carbon in the cap would inhibit potential contaminant movement through the cap and be designed to prevent cap breakthrough within 100 years of placement. Capping is considered to be permanent, and the remaining residuals within the dredge footprint would be covered. Remaining contamination is expected to be effectively sequestered by this treatment action.

ENR and *in situ* sediment treatment options have been retained for consideration in the remedial design, and, if implemented, would sequester contaminants in areas where active dredging and capping are not possible (e.g., utility crossings, bridge abutments, and critical shoreline structures).

Short-Term Effectiveness

Evaluation of short-term effectiveness and impacts of Alternative 5 includes time to achieve RAOs, worker risks and community impacts, resuspension of dredged sediment during implementation, and transport of dredged sediment during implementation.

Time to Achieve RAOs

Alternative 5 is not anticipated to achieve the RAOs, as it is not projected to achieve a post-construction 2,3,7,8-TCDD SWAC of 85 ng/kg and a post-construction total PCBs SWAC of 0.46 mg/kg.

Worker Risks and Community Impacts

As described above, Alternative 5 includes dredging and capping of 62 acres over an estimated 3.2 years, removing 250,000 cy of contaminated sediment in the upper 9 miles of the LPR. Dredge and cap material would be transported by barge to and from the site. All dredged materials would be disposed offsite. Short-term impacts related to construction duration, footprint size, and removal volume are as follows:

- Potential impacts during operations would occur during a 6-month construction season, July 1 to December 31, each year of construction, with operation 24 hours per day, 6 days per week (see Appendix A for specific assumptions on construction season). As noted in Appendix A, construction is assumed not to occur during an annual winter shutdown, January 1 to March 1, or during the dredging restriction period associated with the fish migration window, March 1 to June 30.
- Potential short-term worker risks during the construction period include construction hazards from the use of heavy machinery, open water, and exposure to contaminated sediment. A site-specific health and safety plan would be developed to mitigate risks.
- Potential short-term community impacts during the construction period include vehicular delays as a result of bridge closures, road closures, and railroad crossings due to the transportation of dredged sediment and cap material; locally increased traffic as workers access the construction site, which could increase rate of traffic incidents/ accidents; and light pollution, noise, exhaust, and odor from equipment and 24-hour operations. Although these short-term impacts are unlikely due to proposed institutional controls, exposure to the contaminants could occur with river recreation from direct contact, inhalation, or ingestion of surface waters or contaminated sediment.
- During the active construction period, operations would require property for a 5-acre upland support facility to be used for contractor trailers, sample processing, equipment storage, and parking. [82]
- Habitat and ecological disturbance would occur within the remedial footprint and over the construction duration. Implementation of Alternative 5 would include the restoration of disturbed habitat, and restoration activity would likely be implemented following construction. Therefore, there could be short-term ecological effects within the remedial footprint beyond construction duration and prior to completion of restoration activities. BMPs would be applied to minimize disturbances to the ecosystem and wildlife habitats from the dredging and capping activities outside of the remedial footprints. The impacts from dredging and capping would primarily be from sediment disturbances and resuspension, and potentially from increased noise, exhaust, or river traffic. In addition, marsh disturbances could occur as a result of river bank instability. Contractor access to the waterway for land-based dredging and capping could impact the benthic habitat in the shoals.

Resuspension

The implementation of Alternative 5 would result in sediment resuspension and contaminant release into the water column during construction that could result in short-term exposure of humans or biota to increased concentrations of 2,3,7,8-TCDD, total PCBs, and other collocated

[82] Identification of potential suitable parcels for the upland support facility would be performed during the early stages of the remedial design.

contaminants. It is anticipated that, during design, the potential for resuspension and release to result in recontamination would be evaluated, and BMPs would be designed and implemented to reduce or eliminate the negative impacts on source control and achievement of the RAOs (Section 7.1.3).

The model projections for Alternative 5 evaluate dredging scenarios where either 1 or 3 percent of the dredged sediment is released into the water column, and the model does not simulate near-field settling of particles within the vicinity of the dredge or BMPs that would control residual transport. The model projections show that water column concentrations of 2,3,7,8-TCDD and total PCBs would be higher during construction compared with the No Action alternative (Figure 8-29), with concentrations varying temporally, driven by both the hydrograph used in the models and the assumed dredge sequence and associated concentrations in the dredged sediment. Most of the highest sediment concentrations in the remedial footprint are located between RM 8.3 and RM 10, and the dredge sequencing used in the models addresses this sediment in the latter 2 years of construction. The model projections also show that, following completion of construction, water column concentrations settle down to a level below pre-construction concentrations.

Downstream and Upstream Transport

The implementation of Alternative 5 would result in increased downstream transport of 2,3,7,8-TCDD and total PCBs at RM 8.3 that could result in short-term exposure of humans or biota to increased concentrations during construction below RM 8.3 (Figures 8-30 and 8-32). Projected water column fluxes in this period are also influenced by the hydrograph that is used in the models, the assumed dredge sequence, as well as the construction in the lower 8 miles. Total water column flux at RM 8.3 over the construction period is projected to be approximately 36 to 45 g of 2,3,7,8-TCDD (Figure 8-31) and approximately 128 to 141 kg of total PCBs (Figure 8-33). The implementation of Alternative 5 is not projected to increase transport at RM 0 or RM 15 during construction.

Implementability

Alternative 5 includes dredging of approximately 250,000 cy of sediment, followed by placement of an approximate equivalent volume of capping material. Dredged sediment would be transported to a treatment facility for processing, followed by transport to an offsite disposal facility. The technologies and methods to complete this work are well-established. Necessary equipment (including custom equipment), materials, facilities, and transportation capacity would be available with sufficient lead times.

BMPs would be required during the construction of Alternative 5 to manage dredge residuals and recontamination (Sections 7.1.3 and 8.2.2).

Construction challenges and constraints would be expected to be significant for Alternative 5, given the urban environment of the LPR. Utility crossings, bridge abutments, and critical shoreline structures, discussed in Section 2.3 and Appendix E, could limit or prohibit active dredging and capping in some areas of the Alternative 5 remedial footprint. Dredge offsets and/or engineering controls may be required to protect shoreline structures. In those areas, ENR and/or *in situ* sediment treatment may be evaluated for implementability and effectiveness during remedial design.

Numerous low bridge crossings and other navigational constraints may necessitate specialty, low-profile vessels to move equipment and materials up and down the river, and frequent bridge openings proportionate to the number of projected barge trips for each alternative, to allow barges and tugs to pass. As evidenced during the RM 10.9 and Phase 1 removal actions (Appendix E), inoperable bridges resulted in construction delays. The need for custom equipment, and more generally the optimal methods for material transport, would be evaluated during remedial design to address these constraints and challenges.

Alternative 5 is anticipated to be administratively feasible; however, coordinating with property owners and local governments and obtaining permit equivalents can be anticipated to be time consuming, given the magnitude of the remedy, with the potential to delay construction.

Alternative 5 would be designed to accommodate future anticipated uses of the upper 9 miles of the LPR, including access by waterfront visitors and in-water recreational users.

The in-water construction for the lower 8-mile remedial action is scheduled to begin mid-2022. It is assumed that Alternative 5 implementation would begin in 2024, and the construction periods of the two actions would overlap by several years. Given the estimated schedule, there would be opportunity in the implementation of Alternative 5 to take advantage of any lessons learned during the lower 8-mile remedial design and initial years of remedial construction. Further, there may be opportunities to use common resources (e.g., sediment processing facilities or specialized equipment). The technical and administrative feasibility of such opportunities would be explored during remedial design.

Cost

The total estimated present value cost of Alternative 5 is $321 million (Table 8-4). Costs include the PDI, remedial design, direct and indirect capital costs, and annual and periodic OMM costs for 30 years after the end of construction. The direct capital, annual OMM, and periodic costs include a 25 percent contingency factor to address scope and bid uncertainty (Section 8.2.5). Costs are presented on a net present value basis using a discount rate of 7 percent. The detailed cost estimate for Alternative 5 is provided in Appendix G.

A cost sensitivity analysis presented in Table 8-5 shows the sensitivity of the total estimated cost to discount rates and contingency assumptions. Costs are presented undiscounted and with

discount rates of 7 percent and 1.5 percent (a reasonable expected discount rate for a 30-year project based on information published by the OMB [2018]). Contingency factors of 25 and 35 percent are presented.

8.4 COMPARATIVE ANALYSIS OF THE ALTERNATIVES

The five remedial alternatives are compared with each other based on their relative performance, achievement of the NCP threshold criteria, and degree of achievement of the primary balancing criteria. The comparative analysis is structured according to the IR FS evaluation metrics that are discussed in Section 8.1.4 and summarized in Table 8-1. These include metrics that are based on the general specifications of the remedial alternatives and projections of remedy performance based on the HST and CFT models. A summary of the comparison is provided in Table 8-7.

8.4.1 Threshold Criteria

8.4.1.1 Protection of Human Health and the Environment

Alternatives 2, 3, and 4 would provide overall protection of human health and the environment by remediating source sediment to achieve the RAOs and accelerating the recovery of sediment and water column COC concentrations. These alternatives would reach post-remediation surface sediment SWACs for 2,3,7,8-TCDD of less than 85 ng/kg and for total PCBs of less than 0.46 mg/kg (Figure 8-34). Alternative 1, the No Action alternative, would not provide overall protection of human health and the environment. Alternative 5, while it has the ability to accelerate recovery and progress towards overall protection of human health and the environment, would not accelerate recovery to the same degree as Alternatives 2, 3, or 4, and would not achieve the RAO 1 requirement to reach post-remediation surface sediment SWACs for 2,3,7,8-TCDD of 85 ng/kg and total PCBs of 0.46 mg/kg.

8.4.1.2 Compliance with ARARs

Alternative 1 would comply with ARARs in that it would not trigger any ARARs. All active alternatives would be designed and implemented to comply with all substantive location- and action-specific ARARs. The active alternatives could require one or more ARAR waivers during construction to meet the threshold criterion of compliance with ARARs.

All of the active alternatives are anticipated to improve water quality; however, ARARs for water quality may not be achieved following completion of any of the active remedies. A final remedy for LPR surface water throughout OU4 will be established in the final ROD.

8.4.2 Primary Balancing Criteria

The detailed analyses of the alternatives (Section 8.3) provides the basis for comparing the similarities and differences among the alternatives. An overall comparison of the technical specifications of the alternatives, including remedial footprint area, removal volume, construction duration, and cost, is shown in Figure 8-35; the values are provided in Table 8-7. Figure 8-35, panels a and b, shows the specifications used for the IR FS evaluations, as well as the ranges of remedial footprint areas and volumes resulting from the 100 conditional simulation maps (see Section 8.2.1).

Two approaches were employed to compare the active Alternatives 2, 3, and 4. The first was to characterize the overlap of the model-projected ranges and to evaluate if this overlap is meaningful. To perform this comparison, the overlap of the projected ranges for a given metric for Alternatives 2 and 4 was compared to the range of Alternative 4. Alternatives 2 and 4 were used for this comparison because they represent the maximum difference among the ranges of active alternatives achieving the threshold criteria. Figure 8-36 illustrates how this evaluation was performed. The degree of overlap in the model ranges provides a measure of the similarity in projections for each model performance metric for Alternative 4 in comparison to Alternative 2, under the assumption that the ranges are a reasonable surrogate for overall model uncertainty. If the overlap of the ranges for a given metric was greater than 50 percent of the range of Alternative 4, the differences among the projections were deemed not meaningful to the comparison of the alternatives in the IR FS (i.e., the projected response of the alternatives to the IR was considered similar for a specific metric). The results of this evaluation are presented in Table 8-9.

A second comparison of the performance of Alternatives 2, 3, and 4 evaluated the relative benefit of additional remediation under the larger alternatives (Alternatives 3 and 4) in comparison to the benefit achieved by Alternative 2 for the following subset of metrics (Table 8-10):

- Delineated post-IR SWAC based on the remedial footprint using the CS 37 base map
- Model-projected gross erosional flux in the RM 8.3 to RM 15 reach over the 10-year post-IR period
- Model-projected total water column contaminant load at RM 8.3 over the 10-year post-IR period
- Model-projected average contaminant concentration on depositing fine sediment over the 10-year post-IR period.

These model metrics were selected for use in this comparison because they represent parameters that directly tie to remedial benefit in terms of source strength (gross erosional flux), recontamination potential (water column contaminant load), and recovery potential

(concentration on depositing fine sediment). For this evaluation, relative benefit is defined as the percentage reduction in a given metric for Alternatives 3 and 4 relative to the performance achieved by Alternative 2 for the same metric. The relative benefit is shown as a range, defined as the percent reduction of the upper bounds and the percent reduction of the lower bounds.

For example, as shown in Table 8-10, the 2,3,7,8-TCDD SWAC reduction between Alternative 3 and Alternative 2 is 13 percent. However, the reduction in the total 2,3,7,8-TCDD water column load is only 7 to 9 percent, indicating a diminished relative benefit of the additional remediation under Alternative 3 compared to Alternative 2. In simpler terms, additional remediation to achieve lower SWAC targets produces diminishing returns in terms of reduced recontamination potential as expressed through the water column contaminant load metric.

Comparison of the relationship between additional remediation, as defined by the SWAC reduction, and improved performance, as defined by the improvement in the selected model metrics, provides a measure of the efficiency of additional sediment removal to produce source control benefits. For example, the 2,3,7,8-TCDD SWAC reduction between Alternatives 2 and 3 is 13 percent, as stated above. However, the reduction in 2,3,7,8-TCDD concentrations on depositing particles, a key metric for sediment recovery, is 1 to 4 percent. For metrics that are highly associated with and definitive of source control such as depositing fine sediment concentrations and water column load, the differences between alternatives are small compared to SWAC reduction. Therefore, the relative efficiency of Alternative 3 to Alternative 2 for these metrics is diminished, signifying smaller gain in performance as compared to the additional remediation.

8.4.2.1 Long-Term Effectiveness and Permanence

The degree to which the alternatives achieve long-term effectiveness and permanence is compared among the active alternatives, relative to each other and compared with the No Action alternative.

Source Control and Recovery Potential

The active alternatives would achieve source control by addressing legacy contaminated sediment. Addressing these sources can be expected to result in reduction of contaminant concentrations in the water column, reduced sources to biota,[83] and recovery of sediment outside of the remedial footprint, as cleaner particles settle out of the water column to mix with and bury the existing surface sediment.

[83] Concentrations in surface sediment represent an exposure to biota. Because the specific relationship between sediment concentrations and tissue concentrations is not certain, it is not certain whether contaminant concentrations in biota would be reduced in direct proportion to the reductions in sediment concentrations. However, it is expected that ecological exposure and tissue concentrations would be reduced over some time frame in response to an IR, which is expected to result in a reduction in ecological and human health risk.

Efficacy of RALs Based on the CSM

Alternatives 2, 3, and 4 would achieve the RAO 1 requirement to reach post-IR surface sediment SWACs in RM 8.3 to RM 15 of 85 ng/kg for 2,3,7,8-TCDD and 0.46 mg/kg for total PCBs (Figure 8-34). The RALs resulting from the remedial footprints for Alternatives 2 and 3 are within the range of concentrations identified as source sediment (Section 2.6 and Table 7-2) of 200 to 400 ng/kg for 2,3,7,8-TCDD (Figure 8-37) and equal to 1 mg/kg for total PCBs. Remediating sediment with concentrations within and higher than the source concentration threshold range is expected to achieve source control in the upper 9 miles, as discussed in Section 2.6. The RAL for Alternative 4 (Table 7-2, Figure 8-37) is below the range of 2,3,7,8-TCDD concentrations identified as source sediment, suggesting that the removal of additional sediment volume under this alternative may target sediment that is not acting as a source. Alternative 5 would achieve significant source control, with a 2,3,7,8-TCDD RAL (Table 7-2, Figure 8-37) closer to the high end of the source control concentration range, but would not achieve post-IR SWACs of 85 ng/kg for 2,3,7,8-TCDD, and would not implement a RAL to address total PCBs. Under Alternative 1, long-term SWACs of 2,3,7,8-TCDD and total PCBs decrease somewhat compared to the initial SWACs, due to the remediation of the lower 8 miles and/or ongoing natural recovery, but this alternative would not achieve the RAOs for source control. In summary, Alternatives 2, 3, and 4 would achieve the RAO 1 post-IR surface sediment SWAC requirements in RM 8.3 to RM 15, and the RALs for these three alternatives would to varying degrees address the range of concentrations that represent source sediment that is inhibiting recovery.

Alternatives 2, 3, and 4 would result in post-IR SWACs that represent approximately 91 to 94 percent reductions for 2,3,7,8-TCDD and approximately 81 to 84 percent reductions for total PCBs, compared with the pre-IR estimated SWACs derived from the CS 37 base map (Figure 8-38). The degree of SWAC reduction for Alternatives 2, 3, and 4 relative to pre-IR estimated SWACs varies by less than 3 percent among these alternatives.

The differences in post-IR SWACs for Alternatives 2, 3, and 4 do not signify a difference in attainment of the RAOs for source control. In addition, they cannot be used to signify any meaningful differences in exposure or risk reduction to biota. While it is known that sediment is a source of 2,3,7,8-TCDD and total PCBs to biota, a correlation of biota exposure to the RM 8.3 to RM 15 SWAC has not been established; at this stage, all that can be claimed is that a large reduction in SWAC is expected to result in a large reduction in risk. No data and analyses are available to conclude how the small differences in post-IR SWAC among the alternatives would or would not change risk. The risk reduction achieved by an IR will be an important aspect of the adaptive management phase that follows remediation.

Each successively larger alternative requires a lower 2,3,7,8-TCDD RAL that targets additional area to achieve a lower SWAC. The additional area of the larger alternatives will have progressively lower concentrations, because remedial areas are delineated by targeting 2,3,7,8-

TCDD concentrations from highest to lowest until the SWAC goal is attained (after addressing all areas with total PCB concentration at or above the total PCBs RAL of 1 mg/kg; see Section 7.2.1 and Appendix B). With no targeting error (i.e., all sediment with concentrations above the RAL for a given alternative is remediated), all of the additional area of each successively larger alternative would have concentrations below the RAL of the smaller alternative. For example, the average 2,3,7,8-TCDD concentration within the Alternative 2 remedial footprint is 2,870 ng/kg (Table 8-11), whereas the average concentration decreases to 220 ng/kg within the additional area targeted under Alternative 3 and to 170 ng/kg within the additional area targeted under Alternative 4 (Table 8-11). This idealized evaluation illustrates that concentrations in the incremental areas between successively larger footprints are expected to be much lower than the concentrations in the area targeted under Alternative 2 (Table 8-11).

An evaluation of the average fine fraction of the sediment removed under each successively larger alternative shows that the alternatives with lower 2,3,7,8-TCDD SWAC goals, and subsequently lower RALs, will target coarser sediment to achieve the lower SWAC; the RI data show that higher concentrations of COCs are found on the fine sediment fraction, and COC concentrations are lower on coarser sediment (see Section 2.6). To illustrate this, the RI and current conditions data were used to characterize the average fine sediment fraction expected to be targeted by the Alternative 5 RAL and in the incremental areas between successively larger alternatives (Figure 8-39). The additional sediment targeted under Alternatives 3 and 4 (compared with Alternative 2) includes progressively coarser sediment, with an average fine sediment fraction of approximately 40 percent for the incremental additional sediment targeted under Alternative 3 (compared with Alternative 2) and approximately 35 percent for the additional sediment targeted under Alternative 4. In contrast, the additional sediment targeted under Alternative 2 (compared with Alternative 5) has an average fine sediment fraction at or above the mean of RM 8.3 to RM 15 fine sediment areas of approximately 60 percent, as characterized by the available data (Figure 8-39).

Areas, Masses, and Volumes of Source Removal

The implementation of an IR would be anticipated to remove approximately 300,000 to 500,000 cy of sediment over approximately 75 to 125 acres (considering the range over the 100 conditional simulation maps) under Alternatives 2, 3, and 4 (Figure 8-35, Tables 8-3 and 8-7). The estimated mass of 2,3,7,8-TCDD removed over the upper 0.5 ft of the sediment ranges from 123 g (Alternative 2) to 125 g (Alternative 4), or 92 to 94 percent of the 133 g in RM 8.3 to RM 15 (Figure 8-40 and Table 8-7). Similarly, the estimated mass of total PCBs removed over the upper 0.5 ft of the sediment ranges from 161 kg (Alternative 2) to 167 kg (Alternative 4), or 82 to 85 percent of the 197 kg in RM 8.3 to RM 15. The difference in the mass of 2,3,7,8-TCDD and total PCBs removed by Alternatives 2, 3, and 4 is marginal.

The areas and volumes of sediment source removal increase incrementally from Alternative 2 to Alternative 4 to meet their progressively lower 2,3,7,8-TCDD SWAC targets, without a

commensurate degree of incremental mass of 2,3,7,8-TCDD and total PCB mass removal (Table 8-7). While the overall remedial acreage and volume increases by more than 15 percent from Alternative 2 to Alternative 4, the increase in mass of 2,3,7,8-TCDD and total PCB removed from the top 0.5 ft of the sediment bed is much more modest, increasing by less than 2 percent and 4 percent, respectively.

- Within the 90 acres of the Alternative 2 footprint, approximately 123 g of 2,3,7,8-TCDD is removed in the top 0–0.5 ft interval, or approximately 1.4 g/acre. In the additional 6 acres removed under Alternative 3, an additional 1 g of 2,3,7,8-TCDD is removed, or approximately 0.17 g/acre. Similarly, in the additional 8 acres removed under Alternative 4 (compared with Alternative 3), an additional 1 g of 2,3,7,8-TCDD is removed, or approximately 0.13 g/acre.
- For total PCBs, approximately 161 kg is removed in the top 0–0.5 ft interval under Alternative 2, or approximately 1.8 kg/acre. An additional 2 kg is removed in the additional 6 acres removed under Alternative 3, or approximately 0.3 kg/acre, and an additional 4 kg in the additional 8 acres under Alternative 4, or approximately 0.5 kg/acre.

Distribution of Post-IR Concentrations Relative to Pre-IR Concentrations

Alternatives 2, 3, 4, and 5 address the highest surface sediment concentrations of 2,3,7,8-TCDD and total PCBs. Only Alternatives 2, 3, and 4 would result in a sediment bed with most surface 2,3,7,8-TCDD concentrations below 200 to 400 ng/kg and total PCB concentrations below 1 mg/kg throughout the upper 9 miles (Figures 8-1 and 8-2[84]). The distribution of surface sediment concentrations post-IR is similar for Alternatives 2, 3, and 4 (Figures 8-3 and 8-4). Alternatives 2, 3, and 4 would all provide significant source control by removal of legacy contaminated sediment that is currently inhibiting recovery. Alternative 5 would also remove the highest surface sediment concentrations of 2,3,7,8-TCDD and total PCBs, but would not address some areas with 2,3,7,8-TCDD above 200 to 400 ng/kg and total PCBs above 1 mg/kg that are addressed by the other active alternatives.

Model Projections of Average Sediment Concentrations and Recovery Half-life

Ten years following construction of an IR (model year 18), Alternative 5 is projected to achieve the majority (approximately 92 percent) of the total IR 2,3,7,8-TCDD SWAC reduction achieved by the largest alternative (Alternative 4) relative to Alternative 1 within the RM 8.3 to RM 15 reach (Figure 8-6, panel c). The additional volume removed under Alternative 2 achieves an additional 2,3,7,8-TCDD SWAC reduction of 4 to 6 percent. Alternatives 3 and 4 each achieve

[84] The post-IR concentrations shown on Figures 8-1 through 8-4 reflect substitution of replacement values of 10 ng/kg for 2,3,7,8-TCDD and 0 mg/kg for total PCBs within the active remedial footprints for each alternative. Remaining post-IR concentrations higher than the RALs for each remedial alternative reflect targeting errors, as discussed in Appendix B.

an additional 1 to 2 percent subsequent reduction in 2,3,7,8-TCDD SWAC compared with Alternative 2 and relative to Alternative 1. Projected incremental total PCB SWAC reductions show a similar pattern, in that the majority of the SWAC reduction is achieved by Alternative 5, but with overall smaller SWAC reductions due to ongoing sources (Figure 8-7, panel c). Alternative 5 achieves approximately 78 to 79 percent of the total PCBs SWAC reduction relative to Alternative 1; Alternative 2 achieves an additional reduction of 15 to 18 percent with the additional volume removed. Alternatives 3 and 4 achieve additional reductions of 1 to 2 percent and 2 to 3 percent, respectively, relative to Alternative 2.

Similar incremental reductions are projected over RM 0 to RM 15 (Figures 8-10 and 8-11, panel c), showing that little additional river-wide SWAC reduction is achieved with the additional volumes removed by the larger alternatives.

Implementation of the active alternatives results in 2,3,7,8-TCDD and total PCB SWACs that are nearly an order of magnitude lower than those for the No Action alternative (Figures 8-6 and 8-7). The differences in post-IR 2,3,7,8-TCDD SWACs are projected to persist over the 10-year post-IR period, with an overlap of the ranges of SWAC in RM 8.3 to 15 in year 10 post-IR construction of 35 percent between Alternatives 2 and 4 (Table 8-9). While this overlap is below the threshold of 50 percent used in the comparison of IR alternatives to conclude the differences are not meaningful, it does not signify a difference in attainment of the RAOs for source control (see above discussion in "Efficacy of RALs Based on the CSM"). The overlap of the ranges of total PCB SWAC in RM 8.3 to RM 15 in year 10 post-IR construction is 59 percent between Alternatives 2 and 4 (Table 8-9), indicating that the difference in total PCB SWAC is not considered meaningful to the comparison of IR alternatives.

In the lower 8 miles (RM 0 to RM 8.3), Alternative 1 is accompanied by a projected SWAC reduction of 96 percent for 2,3,7,8-TCDD and 89 percent for total PCBs[85] at the end of 10-year post-IR projection period, due to the implementation of the lower 8-mile remedy alone (Figures 8-8 and 8-9; Table 8-8). Following implementation of an upper 9-mile IR, all of the active alternatives that meet the threshold criteria (Alternatives 2, 3, and 4) provide similar slight increases in projected lower 8-mile SWAC reduction of 98 to 99 percent for 2,3,7,8-TCDD and 90 to 91 percent for total PCBs. The implementation of an IR in the upper 9 miles of the LPR results in additional SWAC reduction in the lower 8 miles, and there is little additional projected benefit to the lower 8 miles of larger remedies in the upper 9 miles (Figures 8-8 and 8-9). The ranges of projected SWACs in RM 0 to RM 8.3 for Alternatives 2 and 4 in year 10 post-IR overlap by 91 percent for 2,3,7,8-TCDD and 88 percent for total PCBs, indicating that the differences in SWACs are not considered meaningful for the comparison of IR alternatives. The ranges of projected SWACs in RM 0 to RM 15 for Alternatives 2 and 4 in year 10 post-IR overlap

[85] Lower 8-mile SWAC reduction is based on the initial SWAC for CS 37 (827 ng/kg for 2,3,7,8-TCDD and 1.53 mg/kg for total PCBs) and range of model projections in model year 18.

by 53 percent for 2,3,7,8-TCDD and 64 percent for total PCBs, indicating that the differences in SWACs are not considered meaningful for the comparison of IR alternatives.

The estimated recovery half-lives for Alternatives 2, 3, and 4 are similar and much shorter (i.e., faster) than the No Action alternative (Figure 8-12 and Table 8-8). Half-lives for Alternatives 2, 3, and 4 range from 8.1 to 18 years for 2,3,7,8-TCDD and 18 to 46 years for total PCBs. The ranges of estimated half-lives for Alternatives 2 and 4 over the 10-year post-IR period overlap by 84 percent for 2,3,7,8-TCDD and 100 percent for total PCBs (Table 8-9). This comparison of the half-lives suggests that larger remedial footprints are not projected to result in more rapid recovery of the sediment from the initial, post-IR SWACs.

Although Alternative 1 provides limited recovery potential that would result from natural recovery and remediation of the lower 8 miles, recovery would be inhibited, however, by the continued presence of source sediment with high contaminant concentrations in the upper 9 miles. Alternatives 2, 3, and 4 result in a high potential for accelerated recovery of the sediment, water column, and tissue. These alternatives address sediment sources that are inhibiting recovery, and following an IR, accelerated recovery would be expected. Alternative 5 also demonstrates improved recovery potential compared to the No Action alternative; however, the extent of recovery could be lower than the other active alternatives as higher surficial sediment concentrations would remain following implementation of Alternative 5.

Model Projections of Average Water Column Concentrations

The active alternatives result in projected 2,3,7,8-TCDD and total PCB water column concentrations that are lower than the No Action alternative, with the projected water column concentrations for Alternatives 2, 3, and 4 in the 10 years following construction being highly similar (Figures 8-13 and 8-14). The overlap of the projected ranges of the mean water column concentrations of the post-IR period for Alternative 2 and Alternative 4 is 74 percent for 2,3,7,8-TCDD and 76 percent for total PCBs (Table 8-9), indicating the similarity among the model projections, and that the difference between the projected concentrations for Alternatives 2, 3, and 4 is not considered meaningful to the comparison of IR FS alternatives. The majority of the water column concentration reductions relative to the No Action alternative are achieved with the implementation of Alternative 5 (Figures 8-13 and 8-14, panel c). The incremental reduction of 2,3,7,8-TCDD water column concentrations resulting from the additional volume removed under Alternative 2 (relative to Alternative 5) is 2 to 4 percent, and approximately 1 percent from the additional volume removed incrementally under Alternatives 3 and 4. For total PCBs, the incremental reductions from additional volume removed under Alternative 2 relative to Alternative 5 is 19 to 25 percent. Additional incremental reductions for the additional volumes removed under Alternatives 3 and 4 are approximately 1 percent. The difference in the reduction of average water column concentrations for 2,3,7,8-TCDD and total PCBs between Alternatives 2, 3, and 4 would be marginal.

The reduction in water column concentrations following implementation of an IR will result in ongoing recovery of unremediated sediment. Alternatives 2, 3, and 4 exhibit very similar improvements in recovery potential in comparison with the No Action alternative.

Model Projections of Average and Cumulative Water Column Loads

Model projections of average and cumulative water column loads predict that the active alternatives would result in a smaller mass of 2,3,7,8-TCDD and total PCBs leaving the upper 9 miles (at RM 8.3) and the LPR (at RM 0) than the No Action alternative (Figures 8-15 through 8-22). Projected upticks in water column loads, likely resulting from high flow events in the model hydrograph (e.g., at model year 12; Figure 8-5), would be significantly reduced with the implementation of an IR (particularly for 2,3,7,8-TCDD), resulting in lower contaminant mass leaving the upper 9 miles. The active alternatives are projected to result in highly similar water column loads in the 10 years following construction. The overlap of the projected ranges of Alternative 2 and Alternative 4 for total water column load over the 10-year post-IR period is 70 percent for both 2,3,7,8-TCDD and total PCBs (Table 8-9), indicating that these three alternatives provide similar reductions of water column loads following implementation of an IR and the differences between the projected loads for Alternatives 2, 3, and 4 are not considered meaningful to the comparison of alternatives.

The majority of the water column load reductions relative to the No Action alternative are achieved with the implementation of Alternative 5 (Figures 8-16, 8-17, 8-20, and 8-21, panel c). The incremental reduction of 2,3,7,8-TCDD water column load at RM 8.3 resulting from the additional volume removed under Alternative 2 (relative to Alternative 5) is 0 to 3 percent, and approximately 1 to 2 percent from the additional volumes removed incrementally under Alternatives 3 and 4 (Figure 8-16, panel c). For total PCBs, the incremental reductions in water column load at RM 8.3 from the additional volume removed under Alternative 2 relative to Alternative 5 is 15 to 19 percent. Additional incremental reductions for the additional volumes removed under Alternatives 3 and 4 is approximately 1 percent (Figure 8-20, panel c). The removal of additional volume results in little additional reduction in water column loads.

In comparison to the 13 percent relative benefit in delineated post-IR 2,3,7,8-TCDD SWAC that differentiates Alternative 3 from Alternative 2 and the 25 percent relative benefit that differentiates Alternative 4 from Alternative 2, the relative benefit in projected water column load at RM 8.3 is modest—7 to 9 percent for Alternative 3 and 6 to 11 percent for Alternative 4 (Table 8-10). This indicates that increasing the size of the remedial footprint to attain a lower SWAC target is comparatively inefficient in terms of its benefit on reducing water column loads. This finding also holds for total PCBs, in which case the efficiency is even lower (Table 8-10).

Model Projections of Average Net and Gross Contaminant Erosional Flux

Model projections of contaminant erosional fluxes predict that average fluxes would be lower for all active alternatives over the 10-year post-IR period than the No Action alternative for both COCs (Figure 8-23 through 8-26), indicating a decreased contaminant load introduced into the water column as a result of active remediation. The gross erosional flux reduction is smaller for total PCBs due to the influence of ongoing sources upstream of the LPRSA. The projected ranges of the average fluxes over the 10-year post-IR period overlap by 64 to 70 percent for 2,3,7,8-TCDD and 76 to 83 percent for total PCBs. The extent of the overlapping projections indicates that Alternatives 2, 3, and 4 are all projected to provide similar reductions of erosional fluxes following implementation of an IR and the projected differences among the alternatives are not considered meaningful to the comparison of the IR alternatives. Similar to water column concentrations and loads, the majority of the erosional flux reduction is achieved under the Alternative 5 removal, with small additional incremental reductions under the successively larger alternatives (Figures 8-23 through 8-26, panel c).

The reduction in erosional flux following implementation of an IR will result in decreased strength of the sediment sources, resulting in the projected reductions in water column concentrations and loads, and will accelerate ongoing recovery of unremediated sediment. Alternatives 2, 3, and 4 exhibit very similar improvements in recovery potential due to reduced erosion flux in comparison with the No Action alternative.

In comparison to the 13 percent relative benefit in delineated post-IR 2,3,7,8-TCDD SWAC that differentiates Alternative 3 from Alternative 2 and the 25 percent relative benefit that differentiates Alternative 4 from Alternative 2, the relative benefit in projected average gross erosional flux is modest—5 to 6 percent for Alternative 3 and 5 to 10 percent for Alternative 4 (Table 8-10). This indicates that increasing the size of the remedial footprint to attain a lower SWAC target is comparatively inefficient in terms of its benefit on reducing gross erosional flux. This finding also holds for total PCBs, in which case the efficiency is even lower (Table 8-10).

Model Projections of Contaminant Concentrations on Depositing Fine Sediment

Model projections of COC concentrations on depositing fine sediment predict that average concentrations over the 10-year post-IR period would be lower than the No Action alternative for all active alternatives for both COCs (Figures 8-27 and 8-28), promoting accelerated recovery of non-remediated areas that are subject to sediment deposition or cyclic deposition and erosion. The reduction is smaller for total PCBs, due to the influence of ongoing sources upstream of the LPRSA. The projected ranges of the average concentrations on depositing fine sediment over the 10-year post-IR period overlap by 62 percent for 2,3,7,8-TCDD and 86 percent for total PCBs. The extent of the overlapping projections indicates that Alternatives 2, 3, and 4 are all projected to provide similar reductions of concentrations on depositing fine sediment

following implementation of an IR and the projected concentration differences among the alternatives are not considered meaningful to the comparison of the IR alternatives.

Similar to the other source control metrics, the majority of the reduction of 2,3,7,8-TCDD concentrations on depositing fine sediment is achieved under Alternative 5, with slight additional reduction under Alternative 2, and little incremental reductions under the successively larger alternatives (Figure 8-27, panel c). For total PCBs, the majority of the reduction is achieved under Alternative 5, with additional reduction under Alternative 2, and little additional incremental reductions with the additional volume removed under Alternatives 3 and 4 (Figure 8-28, panel c)

In comparison to the 13 percent incremental reduction in delineated post-IR 2,3,7,8-TCDD SWAC that differentiates Alternative 3 from Alternative 2 and the 25 percent incremental reduction that differentiates Alternative 4 from Alternative 2, the incremental reductions in projected 2,3,7,8-TCDD concentrations on depositing fine sediment are relatively modest—4 to 5 percent for Alternative 3 and 5 to 8 percent for Alternative 4 (Table 8-10). This indicates that increasing the size of the remedial footprint to attain a lower SWAC target is relatively inefficient in terms of its benefit on reducing depositing fine sediment concentrations of 2,3,7,8-TCDD. This finding also holds for total PCBs, in which case the efficiency is even lower (Table 8-10).

Cap Stability

All of the active alternatives include capping throughout the remedial footprints to a thickness equal to the depth of sediment removal (2 ft plus 6-in. overdredge). A stable cap capable of providing long-term protectiveness can be designed, implemented, and maintained for all active alternatives to isolate contamination remaining in the sediment bed. The conceptual cap design is the same for each active alternative (Appendix F).

Monitoring, Maintenance, and Institutional Controls

Construction monitoring to verify horizontal and vertical sediment cut lines, sediment sampling to evaluate the efficacy of residual management measures, bathymetry surveys to verify proper cap placement, water column monitoring to ensure minimal resuspension and residual impacts, and remedy completion sampling to verify attainment of the target SWACs of 85 ng/kg for 2,3,7,8-TCDD and 0.46 mg/kg for total PCBs specified in RAO 1 would be required for the active alternatives. Sediment sampling to support remedy completion confirmation would be performed within and outside of the remedial footprint from RM 8.3 to RM 15, and it is anticipated that the requirements of this sampling program would be the same for all the active alternatives. The framework for the IR completion assessment process is presented in Appendix H.

Long-term monitoring, including a recovery assessment monitoring phase following IR completion and a subsequent phase of long-term monitoring following selection of a final remedy and issuance of the final ROD, would be required for the active alternatives. Monitoring would occur as part of an adaptive management program to assess system response and recovery and eventually to ensure that final RGs to be established in a final ROD have been achieved. For the IR FS cost estimate, the spatial extent and temporal duration of long-term monitoring is anticipated to be the same for the alternatives.

Cap monitoring and cap maintenance, as needed, would be required for the active alternatives. For the IR FS cost estimate, it is assumed that cap monitoring and cap maintenance are a function of the area of the remedial footprint, and that 5 percent of the capped area would be replaced every 5 years for the first 20 years after construction (i.e., 4.5 acres for Alternative 2, 4.8 acres for Alternative 3, and 5.2 acres for Alternative 4), and then 2.5 percent of the capped area would be replaced for the following 10 years (i.e., 2.3 acres for Alternative 2, 2.4 acres for Alternative 3, and 2.6 acres for Alternative 4). The relative degree of cap maintenance required among the alternatives would increase in direct proportion to the capped area.

All alternatives rely on institutional controls. Existing institutional controls would be retained for Alternatives 2, 3, and 4 until RGs are achieved, at which time there could be revisions to fish consumption advisories. These alternatives would require additional controls in perpetuity to protect the integrity of the cap during and following completion of construction, unless and until some future remedy would address all site risks and allow for the removal of controls. Alternative 5 would require the same institutional controls, but would be less likely to allow for future revisions to fish consumption advisories. Alternative 1 would require existing institutional controls to be retained in perpetuity.

8.4.2.2 Reduction of Toxicity, Mobility, or Volume through Treatment

The active alternatives would use two treatment components to reduce the toxicity and mobility of contaminants through treatment: *ex situ* solidification/stabilization during processing and *in situ* sequestration via capping. The degree to which these reductions are achieved are proportional to the contaminant mass removed and the cap footprint. The mass fraction of 2,3,7,8-TCDD removed from the upper 2.5 ft of the sediment bed ranges from 80 to 85 percent of the total mass in the upper 2.5 ft of the sediment bed in RM 8.3 to RM 15 for the three alternatives (Alternatives 2, 3, and 4) that achieve the threshold criteria (Table 8-7). The mass fraction of total PCBs removed from the upper 2.5 ft of the sediment bed ranges from 64 to 68 percent of the total mass in the upper 2.5 ft of the sediment bed in RM 8.3 to RM 15 for the three alternatives (Alternatives 2, 3, and 4) that achieve the threshold criteria (Table 8-7). Alternative 1 does not provide any reduction in toxicity, mobility, or volume through treatment.

8.4.2.3 Short-Term Effectiveness

Time to Achieve RAOs

Alternatives 2, 3, and 4 would achieve the RAOs in 7.3 to 7.9 years following the start of construction, assuming that the estimated construction durations are 4.3 to 4.9 years and IR completion assessment process would take approximately 3 years, which includes implementation of sediment sampling, analysis of results, potential additional sampling to address uncertainty, and the decision-making process following completion of data collection activities (see Appendix H).

Worker Risks and Community Impacts

The estimated construction durations vary with the area and volume of the remedial footprints, with construction activities assumed to occur 24 hours per day, 6 days per week during the construction season (Table 8-7). Appropriate protection plans and contingency plans would be in place during implementation of an IR to protect workers and the community.

Alternative 2, which has the smallest remedial footprint (of the alternatives that achieve the threshold criteria) and the shortest estimated construction duration, would have the fewest short-term impacts on and risks to workers, communities, and the ecosystem, in a relative comparison with the larger alternatives. These impacts are expected to arise in general proportion to the remedial footprint of the remedial alternatives.[86] Thus, Alternative 4, the alternative with the largest remedial footprint (approximately 14 acres larger than Alternative 2) and longest estimated construction duration (approximately 0.5 years longer than Alternative 2), would have the greatest short-term impacts. For example:

- Alternative 2 would require an estimated 670 barge trips to move dredged sediment,[87] compared with 716 and 778 barge trips required by Alternatives 3 and 4, or 7 percent and 16 percent additional barge trips, respectively.
- Construction of Alternative 2 would require an estimated 448,639 worker hours,[88] compared with 476,899 and 509,681 worker hours required by Alternatives 3 and 4, or 6 and 14 percent additional worker hours, respectively.

While Alternatives 2, 3, and 4 are all estimated to be complete within 5 years, the larger alternatives have a greater potential to extend into another construction season if delays are encountered, which would result in another season of worker risks and community impact.

[86] The extent to which habitat and ecological disturbance may increase in proportion to the remedial footprint is uncertain and will depend on final delineation of the remedial footprint during the PDI.
[87] Assuming a 500 cy barge.
[88] Assuming an average work crew of 30 workers per day.

Resuspension

Resuspension of contaminants during construction is projected to be generally similar for Alternatives 2, 3, and 4, as evidenced in model projections of annual average water column concentrations (Figure 8-29). During active construction (model years 4 to 8), average annual water column concentrations for the active alternatives are higher than the No Action alternative. In model year 6, annual average water column concentrations are higher for Alternatives 2 and 3, and in model year 7, Alternative 4 has the highest average annual water column concentrations (construction for Alternative 5 has ended by model year 7). These variations are due to the timing of dredging of certain areas in the river; dredging in areas with higher sediment concentrations results in higher short-term water column concentrations. For all of the alternatives, annual average water column concentrations at the completion of construction (model year 8) are generally lower than pre-construction concentrations.

Downstream and Upstream Transport

At RM 15, there is little projected impact of an IR implementation, as the average annual and cumulative net downstream water column load is nearly the same for the active and No Action alternatives (Figures 8-30 through 8-33, panel a). At RM 8.3, the implementation of an IR is projected to increase the downstream loads of 2,3,7,8-TCDD and total PCBs in the water column during construction, compared to the No Action alternative, with similar increases for Alternatives 2, 3, and 4 (Figures 8-30 through 8-33, panel b). In model year 8, the water column loads for the active alternatives are at or near the projected No Action load at RM 8.3. The implementation of an IR is projected to have a small impact on the water column loads at RM 0, evidenced in the projections of total load, which are generally similar for all alternatives over the construction period (Figures 8-30 through 8-33, panel c).

8.4.2.4 Implementability

The technologies and methods to perform the active alternatives are well established. Necessary equipment, materials, facilities, and transportation capacity would be available for the active alternatives with sufficient lead times. The active alternatives would require BMPs during implementation to manage dredge residuals and potential recontamination. The construction of an IR would face implementability challenges in the upper 9 miles of the LPR due to the urban environment. Specific challenges that could impact dredging and would need to be considered during remedial design and implementation include utility crossings, existing shoreline structures, in-water bridge structures, and hard river bottom. For example, designing and implementing the remedy where the footprint abuts hardened or engineered shoreline could require significant effort to avoid damaging engineered shoreline structures or to rebuild or replace failing structures, and/or result in lower production rates or unanticipated delays. Alternative 2 abuts an estimated 37,792 linear feet of hardened shoreline, compared with 39,551 and 41,454 linear feet abutted by Alternatives 3 and 4, or 5 and 10 percent additional hardened shoreline, respectively.

The transport of materials up and down the LPR would also present implementability challenges due to low clearance and/or narrow bridges, which could necessitate custom or specialized equipment, as well as transiting tugs and barges through the lower 8.3 miles during active remediation of that reach of the river. Implementation of an IR could require additional removal in and/or around the RM 10.9 removal area, which could introduce additional implementability challenges associated with protecting the existing armored cap over the remediated area. The extent of remediation in and/or around the RM 10.9 area will be determined during the remedial design when the remedial footprint is finalized.

While the alternatives can be designed to address these challenges, the active alternatives with the larger remedial footprints would present greater challenges and constraints simply by the need to dredge in more areas and over a longer time frame. Although implementability challenges would be similar in type for all active alternatives, the degree of the challenges can be anticipated to increase in general proportion to the size of the remedial footprint.

8.4.2.5 Cost

Alternatives that achieve the RAOs (Alternatives 2, 3, and 4) are estimated to have a present value cost from $420 million to $468 million (Table 8-4). There are no remedial response costs associated with Alternative 1. Alternative 5 is estimated to cost $321 million. Costs that are assumed to be the same for the active alternatives include the PDI and remedial design, long-term monitoring, and periodic sediment sampling (which includes remedy completion confirmation sampling). Other costs vary with area, volume, and construction duration. The cost estimate assumes that long-term monitoring and maintenance will occur over a 30-year period following completion of construction, including both recovery assessment monitoring following an IR and additional long-term monitoring to be specified when a final remedy is selected under a final ROD.

The NCP requires consideration of the benefits achieved by the remedial alternatives relative to their cost, where a remedy is deemed cost-effective *"if its costs are proportional to its overall effectiveness" (40 CFR §300.430(f)(1)(ii)(D))*. Alternatives 2, 3, and 4 all achieve the RAOs for an IR, but with an additional cost of $21 million and $48 million for Alternatives 3 and 4, respectively, compared with Alternative 2 (Figure 8-41). The targeting of high concentration sediment results in a 2,3,7,8-TCDD SWAC reduction of 91 percent for Alternative 2, with an additional 1 percent SWAC reduction for Alternative 3, at an additional cost of $21 million, and an additional 2 percent SWAC reduction for Alternative 4, at an additional cost of $48 million (Figure 8-42). The targeting of high concentration sediment results in a total PCBs SWAC reduction of 81 percent for Alternative 2, with an additional 1 percent reduction for Alternative 3, at an additional cost of $21 million, and an additional 2 percent for Alternative 4, at an additional cost of $48 million (Figure 8-42). The projected water column metrics indicative of source control and recovery potential (water column load at RM 8.3 [Figure 8-43], erosion

flux [Figure 8-44], and concentrations on depositing fine sediment [Figure 8-45]) show that no meaningful additional benefits are realized for the additional costs of the larger alternatives.

Alternative 4, with the largest remedial footprint and highest cost, does not provide additional source control compared with Alternatives 2 and 3. Alternatives 2, 3, and 4 all remove surface sediment identified as inhibiting recovery (i.e., 2,3,7,8-TCDD on the order of 200 to 400 ng/kg and total PCBs above 1 mg/kg). The additional sediment removal (1 to 2 percent more mass of 2,3,7,8-TCDD and less than 3 percent 2,3,7,8-TCDD SWAC reduction from initial SWACs) is not projected to increase the rate of longer-term recovery. In addition, Alternative 4 does not provide substantial economies of scale relative to Alternative 2. For the additional cost, the alternatives with the larger remedial footprints (Alternative 3 and 4) do not provide demonstrable additional benefit over Alternative 2, relative to the overall goal of the IR to address and control sources.

Cost Sensitivity

The cost sensitivity analysis compares cost estimates for the alternatives with varying discount rates and contingency estimates (Table 8-5). The total net present value costs, discounted at a rate of 7 percent, are approximately 20 percent lower than the undiscounted costs. Total net present value costs discounted at a rate of 1.5 percent (a reasonable expected discount rate for a 30-year project based on information published by the OMB [2018]) are approximately 17 to 19 percent higher than those discounted at the EPA default discount rate of 7 percent. Increasing the contingency from 25 percent, assumed in the cost estimate, to 35 percent, increases total net present value costs by approximately 6 to 7 percent.

As part of the IR FS discussions with EPA and NJDEP, the CPG agreed to perform two cost sensitivity analyses: (1) to compare mechanical and hydraulic dredging, and (2) to compare disposal at Subtitle C and Subtitle D landfills. To address the first, a screening-level evaluation performed for Alternative 3 shows that estimated hydraulic dredging costs are approximately 16 percent higher than mechanical dredging costs (Appendix G). The hydraulic dredging cost estimate assumes higher dredging production rates, significant debris handling, hydraulic pipeline transport, and processing at a dewatering facility to be constructed within or near the mouth of the Passaic River.[89] The costs for equipment, a pipeline, and a processing facility are based on unit costs from similar projects for the purposes of this FS-level cost analysis. As discussed in Section 5.1.7.3, there are significant implementability issues associated with hydraulic dredging in the LPR, and the appropriate dredging methods will be determined during the remedial design. To address the second, costs were compared for the four active alternatives assuming all sediment would be disposed at either a Subtitle C or a Subtitle D landfill (Appendix G). Overall costs were 15 to 17 percent lower when sediment was disposed at Subtitle D landfill compared with disposal at a Subtitle C landfill.

[89] Evaluation of potential suitable locations for this facility would be performed during remedial design.

8.4.3 Green and Sustainable Remediation Considerations

A GSR evaluation of a range of metrics was performed to compare the environmental, social, and economic impacts of implementation of an IR. While not a formal CERCLA evaluation criterion, the GSR evaluation provides a way to measure the sustainability of an IR, recognizing the common goal of EPA and the CPG to protect the environment and minimize community impacts. While the concept of "sustainability" is not one of the NCP's criteria, EPA may consider "greener" activities when those can be incorporated into alternatives and evaluated under specific NCP criteria. Numerous agencies and organizations have provided guidance on GSR considerations during the CERCLA process (USEPA 2016c; ITRC 2011; NAVFAC 2012a,b; NRC 2014; USACE 2012).

The active alternatives were evaluated using the SiteWise™ Version 3 Tool, developed jointly by the U.S. Navy, USACE, and Battelle (NAVFAC 2013). The evaluation considers design assumptions including construction duration, remedial footprint area, construction methods, material consumption,[90] and volumes for material transport, treatment, and disposal. PDIs and post-construction monitoring activities were not considered in the evaluation.

Four model outputs were selected for evaluation of GSR impacts: greenhouse gas emissions, total energy used, water consumption, and potential injuries. Alternative 1 has no active construction, and therefore zero impacts in the GSR evaluation. Table 8-12 presents the results as a qualitative comparison of the GSR impacts for the active alternatives and using proportionally sized bar symbols. The GSR impacts are proportional to remedy size; the smallest remedial footprint has the smallest impacts, and impacts increase with increasing size of remedial footprints. The primary contributors to greenhouse gas emissions and energy consumption are equipment use during dredging and capping remediation activities, sediment dewatering, and the transportation of equipment and materials on and off the site. The SiteWise™ modeled water consumption is calculated from estimated electrical operations to decant barge water and stabilize sediment, which is a function of water usage associated with coal-based electrical power production (AWI 2007). Potential injuries are most influenced by the duration and worker transportation via roads and flights. A more detailed description of the evaluation is presented in Appendix I.

8.5 COMPARATIVE ANALYSIS SUMMARY

Five source control IR alternatives were evaluated and compared for their ability to achieve the RAOs in the upper 9 miles of the LPR (Table 8-7). Based on the data evaluations performed in the RI, recovery is inhibited by the erosion and redeposition of sediment with high concentrations of 2,3,7,8-TCDD and total PCBs. Controlling these sediment sources will result

[90] Material consumption and associated operations inputs were developed to the extent that representative parameters were available in the SiteWise™ tool.

in accelerated recovery in the water column and subsequent recovery in areas of unremediated sediment outside of the remedial footprint. High concentrations in source sediment are those above approximately 200 to 400 ng/kg for 2,3,7,8-TCDD and 1 mg/kg for total PCBs (Section 2.6). Addressing sediment with concentrations less than these values would not be expected to contribute substantially to recovery.

The following subsections summarize the results of the comparison of the IR FS alternatives against the NCP threshold and primary balancing criteria (Table 8-7):

8.5.1 Threshold Criteria

- Protection of Human Health and the Environment—Of the five alternatives evaluated in this IR FS, Alternatives 2, 3, and 4 achieve the IR FS metrics for the threshold criteria, with the ability to achieve the RAOs and progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations. Alternative 5 would promote accelerated recovery of sediment and water column COC concentrations, but not to the degree of Alternatives 2, 3, or 4. Alternative 5 also would not achieve the RAOs. Alternative 1 would not achieve the RAOs or accelerate recovery.

- Compliance with ARARs—Alternative 1 would not trigger ARARs. Alternatives 2, 3, 4, and 5 have the ability to comply with ARARs.

8.5.2 Primary Balancing Criteria

- **Long-term Effectiveness and Permanence**—Alternatives 2, 3, and 4 achieve a high degree of performance for this criterion (Table 8-7). All three of these alternatives provide source control that will reduce concentrations in the water column and promote accelerated recovery in the unremediated areas of the sediment bed.
  - The RALs for 2,3,7,8-TCDD and total PCBs under Alternatives 2, 3, and 4 fall within or below the concentration ranges for particles depositing to the sediment bed and inhibiting recovery, based on the CSM (Section 2.6), indicating that all three alternatives will provide effective source control. The 2,3,7,8-TCDD surface RAL of 164 ng/kg for Alternative 4 is less than the low end of 200 to 400 ng/kg range based on the data evaluation of depositing particle concentration ranges, indicating this alternative may include areas that are currently subject to natural recovery in the active footprint.
  - The areas and volumes of sediment source removal increase incrementally from Alternative 2 to Alternative 4 to meet their progressively lower 2,3,7,8-TCDD SWAC targets, without a commensurate degree of incremental mass of 2,3,7,8-TCDD and total PCB mass removal (Table 8-7). While the overall remedial acreage and volume

increases by more than 15 percent from Alternative 2 to Alternative 4, the increase in mass of 2,3,7,8-TCDD and total PCB removed from the top 0.5 ft of the sediment bed is much more modest, increasing by less than 2 and 4 percent, respectively.

1. Within the 90 acres of the Alternative 2 footprint, approximately 123 g of 2,3,7,8-TCDD is removed in the top 0–0.5 ft interval, or approximately 1.4 g/acre. In the additional 6 acres removed under Alternative 3, an additional 1 g of 2,3,7,8-TCDD is removed, or approximately 0.17 g/acre. Similarly, in the additional 8 acres removed under Alternative 4 (compared with Alternative 3), an additional 1 g of 2,3,7,8-TCDD is removed, or approximately 0.13 g/acre.
2. For total PCBs, approximately 161 kg is removed in the top 0–0.5 ft interval under Alternative 2, or approximately 1.8 kg/acre. An additional 2 kg is removed in the additional 6 acres removed under Alternative 3, or approximately 0.3 kg/acre, and an additional 4 kg in the additional 8 acres under Alternative 4, or approximately 0.5 kg/acre.

– By the nature of the targeting, the highest concentrations are targeted by the smallest alternative. Progressively lower concentrations are targeted as remedial area is added to achieve the lower SWACs of the larger alternatives. The decision to add area to the remedial footprint is based on concentrations on an 80-ft on-center grid overlaid on the map generated using geostatistics. The average 2,3,7,8-TCDD concentration of these values is 2,870 ng/kg for Alternative 2. It is 220 ng/kg in the 6 acres added with Alternative 3 and 170 ng/kg in the 8 acres added with Alternative 4.[91]
– The additional sediment targeted under Alternatives 3 and 4 (compared with Alternative 2) is progressively coarser than deposits in the LPR that are classified as fine sediment[92] (Figure 8-39), providing further evidence that the additional volume of sediment addressed by the larger alternatives, and particularly Alternative 4, may not represent source material.
– The change in the distribution of post-IR concentrations relative to pre-IR concentrations is similar for Alternatives 2, 3, and 4 (Figures 8-1a-c, 8-2a-c). The frequency distributions of concentrations following IR implementation (Figures 8-3 and 8-4) show minor differences among the active remedial alternatives, reflecting the variation in the estimated RALs needed to achieve the differing 2,3,7,8-TCDD target SWAC that differentiates the alternatives. (Occasional post-IR concentrations

[91] The extent to which the average of the 80-ft on-center concentrations are reflective of the area-weighted mean of the remediated areas depends on the variability of the underlying concentration field and the targeting error embedded in the footprint delineation, both of which may influence the remedial benefit associated with the incremental areas between alternatives. When adding lower concentration incremental areas for Alternatives 3 and 4, targeting error makes the area-weighted means higher than the 80-ft on-center concentrations.
[92] As discussed in Section 2.6, high concentrations of 2,3,7,8-TCDD and total PCBs are associated with fine sediment.

higher than the RALs for each active remedial alternative reflect targeting errors, as discussed in Appendix B). During the remedial design, PDI data will be collected to better constrain data variability and to minimize targeting error when delineating the IR footprint. A second round of PDI sediment sampling (see Section 7.1.6) will be implemented to achieve these outcomes.

  - The active alternatives provide similar results based on the overlapping ranges of all nine of the modeling projection metrics identified in Table 8-1. Eight of the nine have greater than 50 percent overlap for 2,3,7,8-TCDD, and all nine have greater than 50 percent overlap for total PCBs. This degree of overlap indicates that the alternatives provide similar results and that the differences in the projections among the alternatives are not considered meaningful to the comparison of the IR FS alternatives (Tables 8-8 and 8-9). Alternatives 2, 3, and 4 provide similar degrees of recovery potential and would result in accelerated recovery of the sediment and water column, manifested by reductions of erosion flux of contaminants from the sediment bed, which would result in reduced concentrations on depositing fine sediment and downstream loads of 2,3,7,8-TCDD and total PCBs. The recovery half-lives for these three alternatives are similar, indicating they would have similar potential to achieve future RGs in a reasonable time frame.
  - The additional remediation needed to reach lower target 2,3,7,8-TCDD SWACs under Alternatives 3 and 4 compared with Alternative 2 provides substantially lower relative benefit for other key source control metrics, including projected gross erosional flux, water column contaminant load, and contaminant concentrations on depositing fine sediment (Table 8-10). For example, although Alternative 4 would provide 25 percent more in initial 2,3,7,8-TCDD SWAC reduction in comparison to Alternative 2 (which results in a post-IR SWAC below the RAO 1 target), it would result in reductions of only approximately 5 to 10 percent for the other metrics. This indicates that increasing the size of the remedial footprint to attain a lower SWAC target is comparatively inefficient in terms of reduced contaminant source strength, reduced recontamination potential, and increased recovery potential. The same finding holds for total PCBs, in which case the efficiency is even lower (Table 8-10).

- **Reduction of Toxicity, Mobility, or Volume through Treatment—**For Alternatives 2, 3, and 4, the estimated mass removed in the upper 2.5 ft of the sediment bed from RM 8.3 to RM 15 ranges from 590 g to 630 g of 2,3,7,8-TCDD and 810 kg to 860 kg of total PCBs (Table 8-7). The small additional mass removal for Alternatives 3 and 4 compared to Alternative 2 reflects the incrementally lower concentrations in the additional sediment that would be removed under the larger alternatives.
- **Short-term Effectiveness—**Alternatives 3 and 4 have larger remedial footprints than Alternative 2, with comparatively greater mass and volume removals and longer construction durations. Alternative 2, which has the smallest remedial footprint and the shortest estimated construction duration, would have the least short-term impacts on

risks to workers, communities, and the ecosystem. Conversely, Alternative 4, the alternative with the largest remedial footprint and longest estimated construction duration, would have the largest short-term impacts. For example, Alternative 2 would require an estimated 670 barge trips to transport dredged sediment,[93] compared with 716 and 778 barge trips required by Alternatives 3 and 4, or 7 and 16 percent additional barge trips, respectively. Short-term impacts to workers and the community are proportionally greater with the larger footprints associated with Alternatives 3 and 4, compared with Alternative 2. Construction of Alternative 2 would require an estimated 448,639 worker hours,[94] compared with 476,899 and 509,681 worker hours required by Alternatives 3 and 4, or 6 and 14 percent additional worker hours, respectively.

- **Implementability**—The increasing size and scope of the three alternatives would result in comparable increases in implementability challenges that include logistical and construction constraints associated with the presence of numerous utility crossings, shoreline structures, and bridges. For example, designing and implementing the remedy where the footprint abuts hardened or engineered shoreline could require significant effort to avoid damaging engineered shoreline structures or to rebuild or replace failing structures, and/or result in lower production rates or unanticipated delays. Alternative 2 abuts an estimated 37,792 linear feet of hardened shoreline, compared with 39,551 and 41,454 linear feet abutted by Alternatives 3 and 4, or 5 and 10 percent additional hardened shoreline, respectively. Navigational constraints, including bridges with low clearances, shallow water, and strong currents, will present challenges for the transport of equipment and materials along the waterway. All of these challenges are anticipated to be significant, and most would increase in proportion to the size of the remedial footprint and the construction time frame, and therefore would be larger for Alternative 3 compared with Alternative 2, and larger for Alternative 4 compared with Alternatives 2 and 3.
- **Cost**—The estimated costs for the alternatives increase with remedial footprint size and removal volume. The additional costs for Alternatives 3 and 4 do not result in demonstrable additional benefit and/or efficiencies over Alternative 2, as all three alternatives fully achieve the established RAOs for a source control IR, and the alternatives with larger remedial footprints are not projected to result in faster recovery rates following remedy completion. Together with the implementation of the lower 8-mile remedy, an IR in the upper 9 miles based on Alternative 2, 3, or 4 is expected to promote significant river-wide recovery, with the degree of overall recovery similar for all of these alternatives. Alternative 2 achieves the source control RAOs with the least volume of sediment removal for the lowest cost.

[93] Assuming a 500 cy barge.
[94] Assuming an average work crew of 30 workers per day.

8.5.3 Conclusion

Alternatives 2, 3, and 4 all meet the IR FS metrics for the threshold criteria:

- The ability to achieve the RAOs
- The ability to progress towards overall protection of human health and the environment by accelerating the recovery of sediment and water column COC concentrations
- The ability to comply with ARARs.

The three alternatives achieve a high degree of long-term effectiveness and permanence (Table 8-7). All three of these alternatives provide source control that will reduce concentrations in the water column and promote accelerated recovery. The RALs for 2,3,7,8-TCDD associated with Alternatives 2, 3, and 4 are to varying degrees within or below the range of target concentrations that define source sediment. Alternative 2 ranks comparatively higher than Alternatives 3 and 4 for two critical balancing criteria—short-term effectiveness and implementability. Alternatives 3 and 4 provide slight increases of approximately 3 and 7 percent, respectively, in the reduction of toxicity, mobility, and volume through treatment compared with Alternative 2.

Considering cost with respect to overall effectiveness, the larger remedial footprints and additional costs of Alternative 3 (5 percent more in cost) and Alternative 4 (11 percent more in cost) compared with Alternative 2 do not provide significant additional benefit or efficiencies with respect to meeting the source control objectives of an IR. This lack of significant benefit or efficiency is more pronounced comparing Alternative 4 to Alternative 2 as opposed to comparing Alternative 3 to Alternative 2.

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Figures

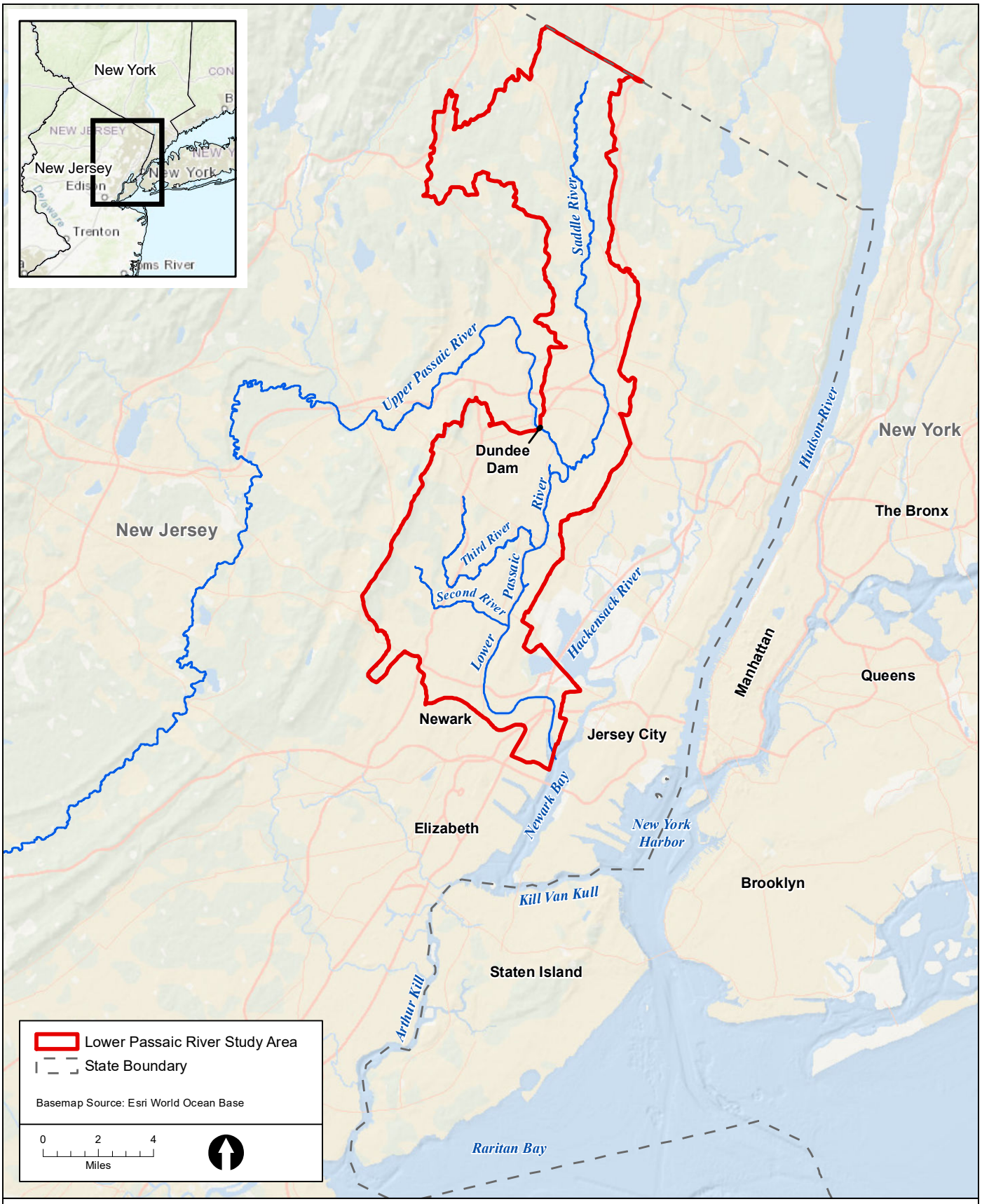

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Figure ES-1.
Lower Passaic River Study Area and Surrounding Regions
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

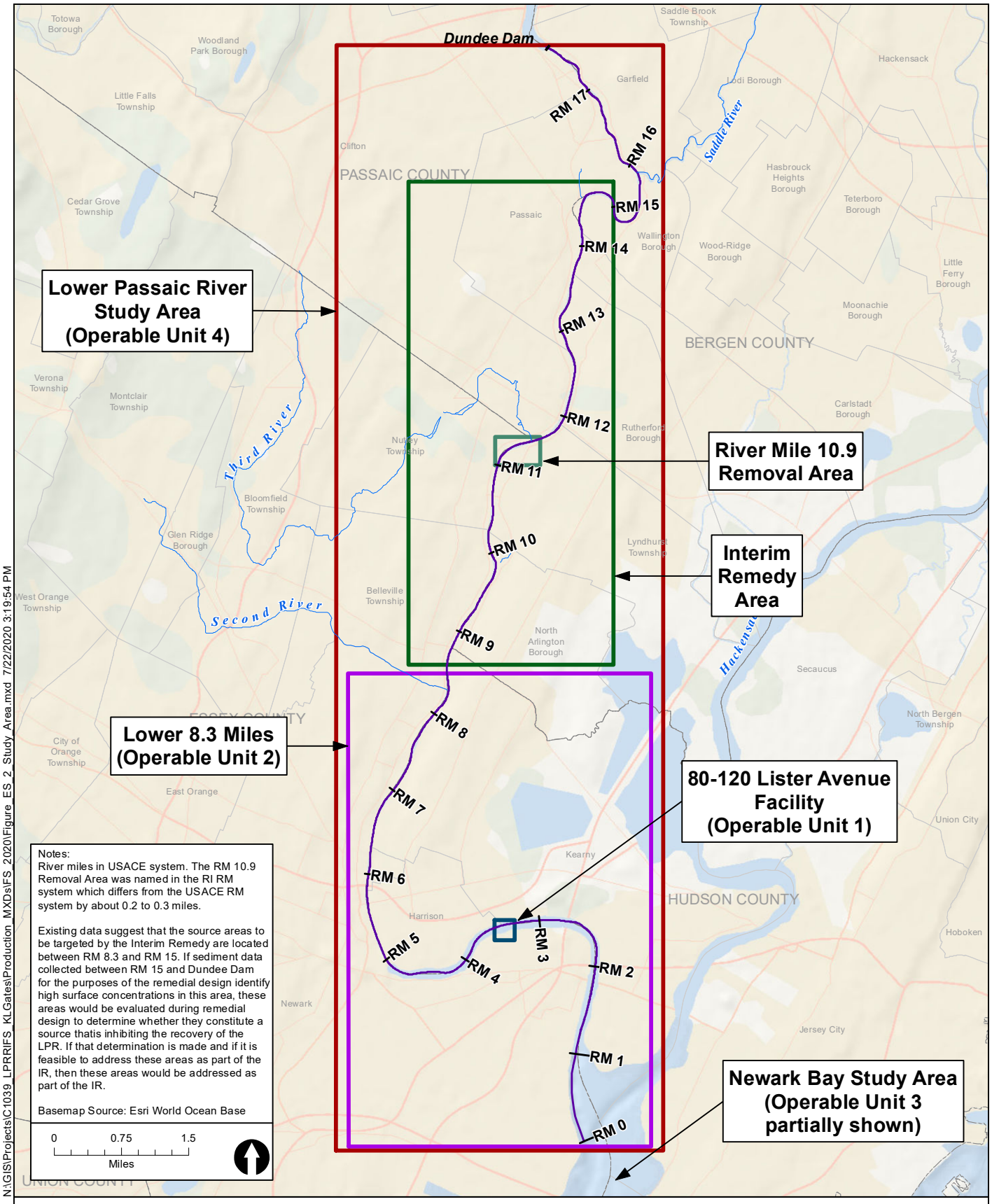

Figure ES-2.
Lower Passaic River Study Area Operable Units and Remedial Action Areas
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

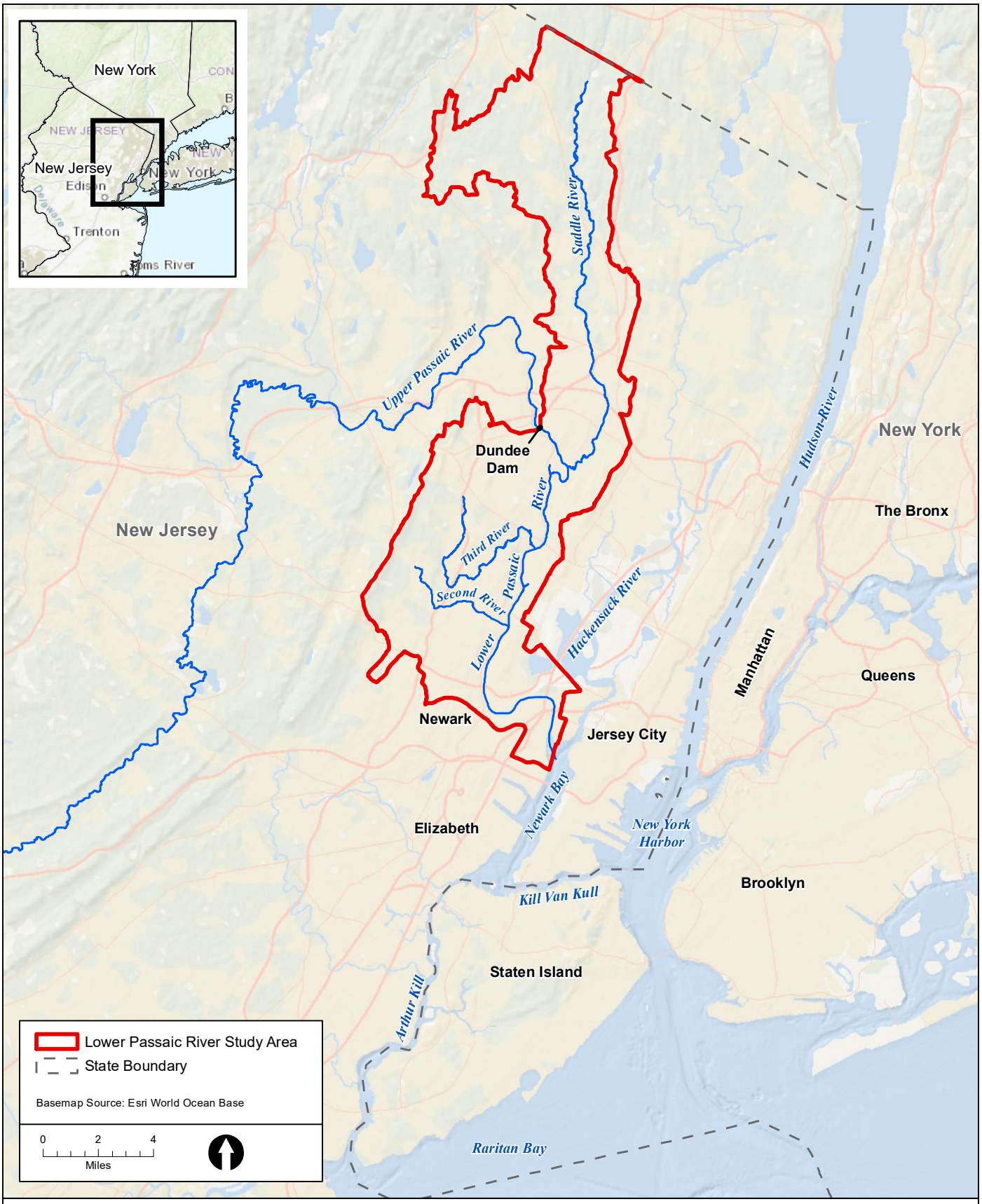

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Figure 1-1.
Lower Passaic River Study Area and Surrounding Regions
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

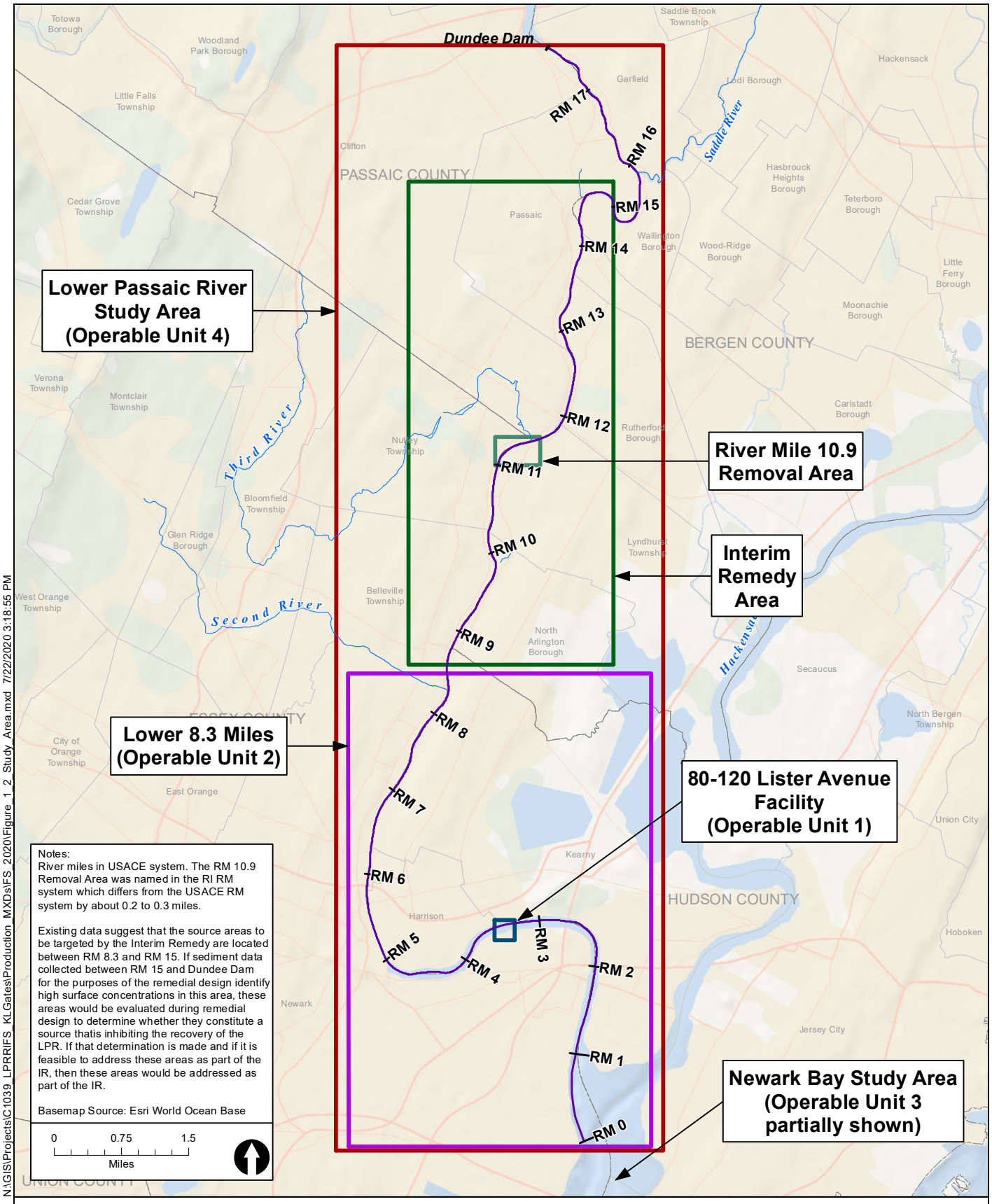
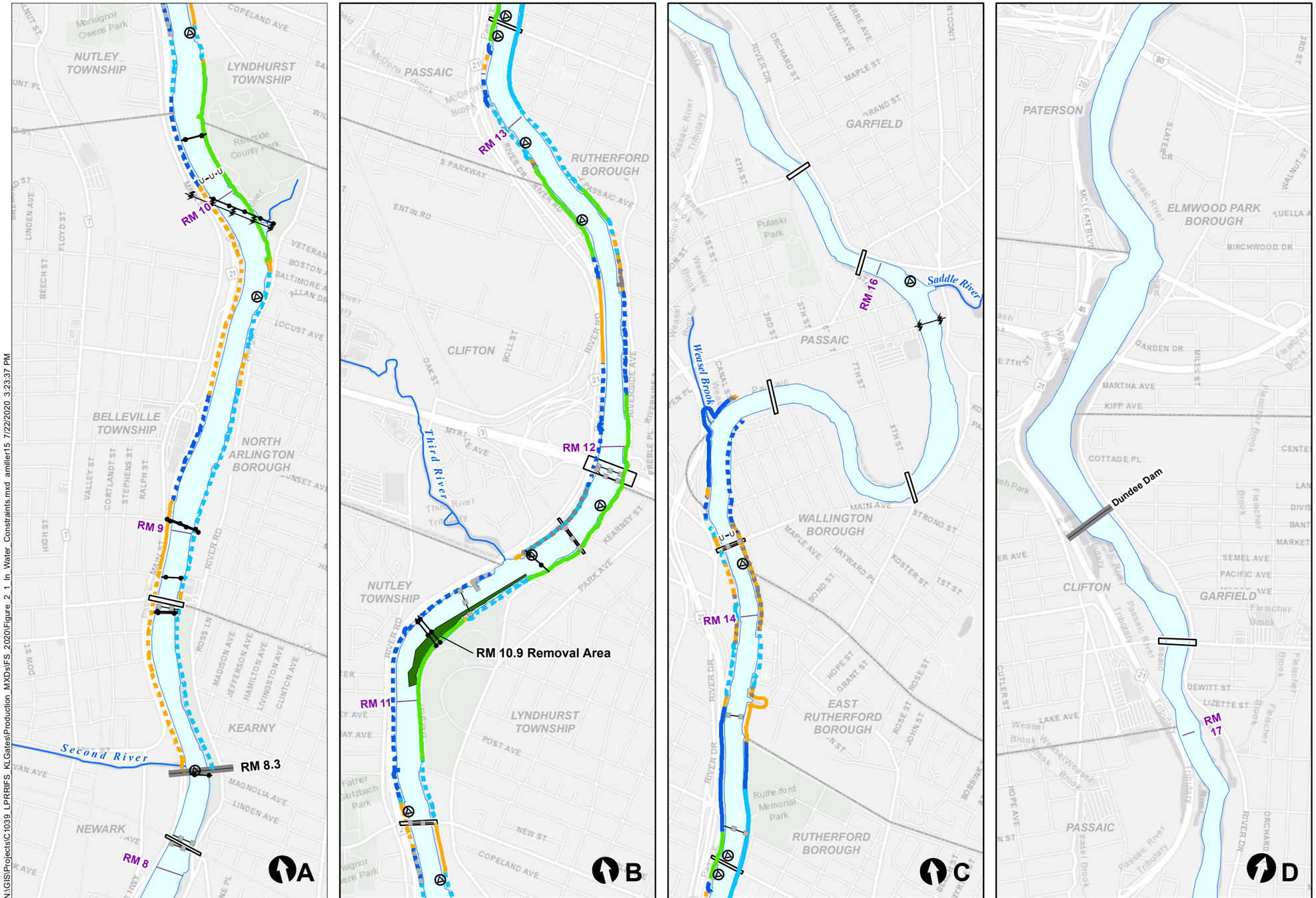


Figure 1-2.
Lower Passaic River Study Area Operable Units and Remedial Action Areas
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



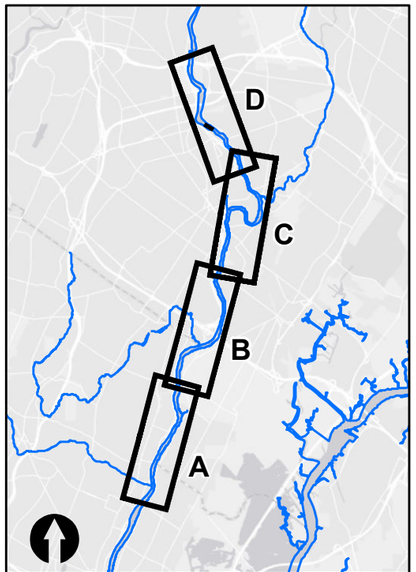
Shore Type, Condition

- Bulkhead, Poor to Failing
- Bulkhead, Fair
- Bulkhead, Good
- Engineered Riprap, Poor to Failing
- Engineered Riprap, Fair
- Engineered Riprap, Good
- Nonengineered Riprap, Poor to Failing
- Nonengineered Riprap, Fair
- Nonengineered Riprap, Good
- Natural; Natural, Fair
- Debris
- Cable Utility Crossing
- Pipeline Utility Crossing
- Unknown Utility Crossing
- Cable Overhead
- Upper 9-mile Study Area Boundary
- Lower Passaic River
- River Mile (USACE)
- Municipal Boundary
- Bridge

Note:
Bridge abutments, utility areas, debris, and shoreline structures (e.g., riprap, bulkheads, piers) may require safe dredging offsets and/or engineering controls to avoid damage to infrastructure. Dredging offsets would be based on structure/material type, condition, and adjacent structures and roadways.

River miles in USACE system. The RM 10.9 Removal Area was named in the RI RM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

Basemap Source: Esri World Ocean Base



0 750 1,500
Feet

Figure 2-1.
Summary of Waterways Condition Assessment in the Upper 9 Miles
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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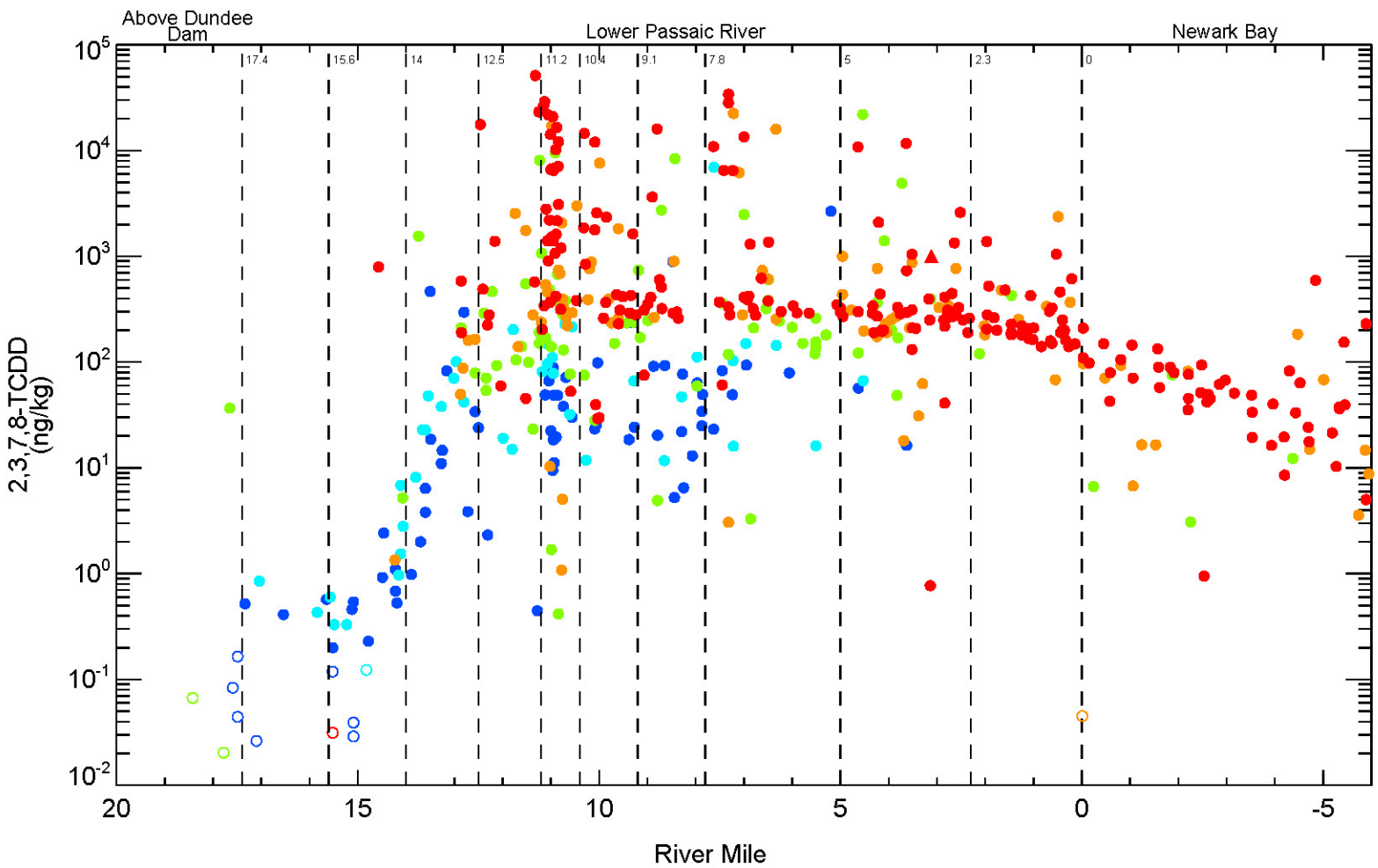
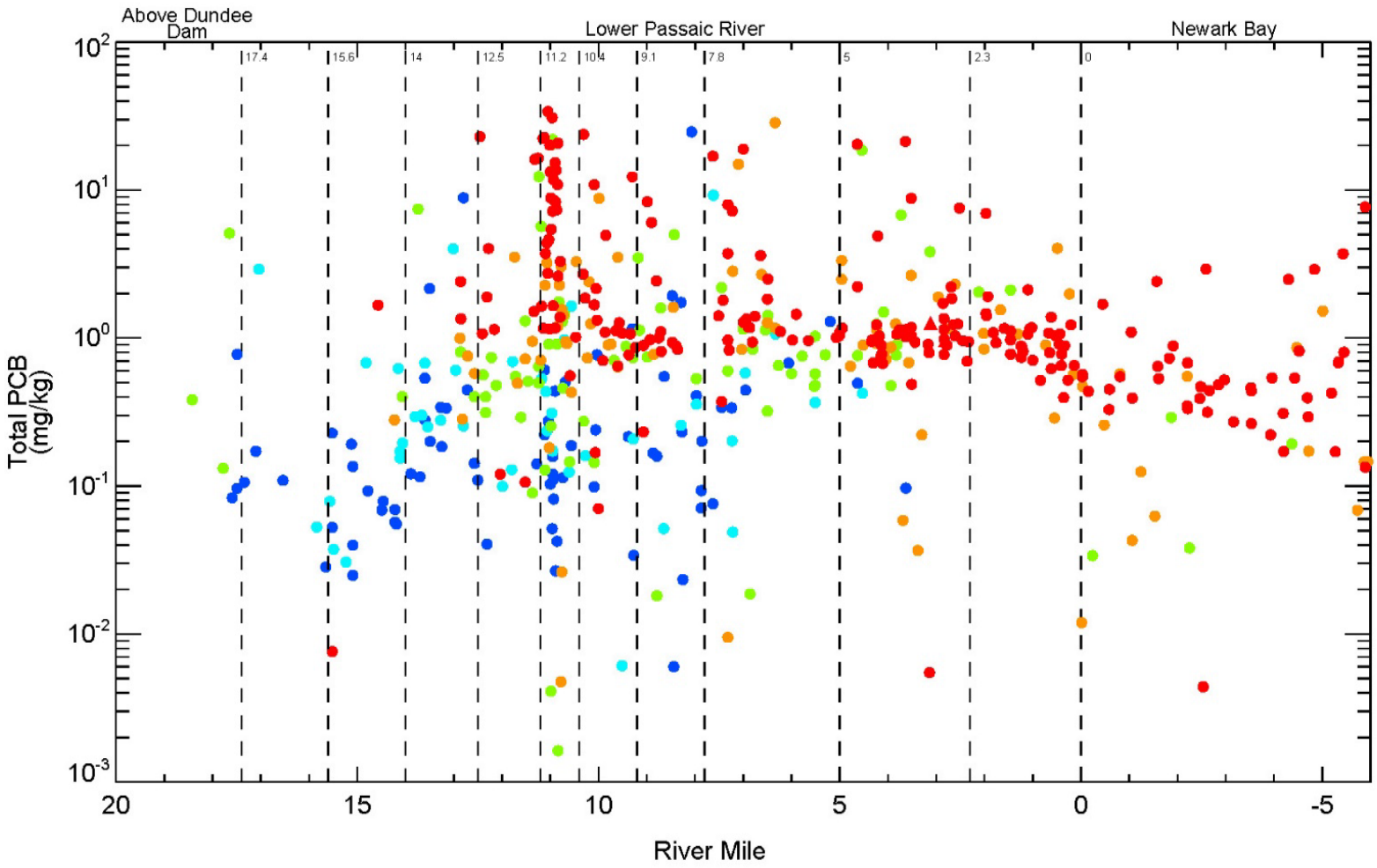


Plots include all post-2005 data with bottom depths less than 6 inches.
Non-detects (NDs) plotted with open symbols at 1/2 the Detection limit (DL). Dashed lines indicate RI reach boundaries.
Excluded samples are without % fines data.
River Miles in RI RM system, which differs from the USACE RM system (used in this IR FS) by about 0.2 to 0.3 miles.

% Fines
- 0 - 10
- 10 - 20
- 20 - 40
- 40 - 60
- 60 - 100

- Passaic River / Newark Bay Data
- TSI Phase I and II Removal Area
- Non-Detect

Figure 2-2a.
2,3,7,8-TCDD Concentrations in the Surface Sediment of LPR and Newark Bay
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



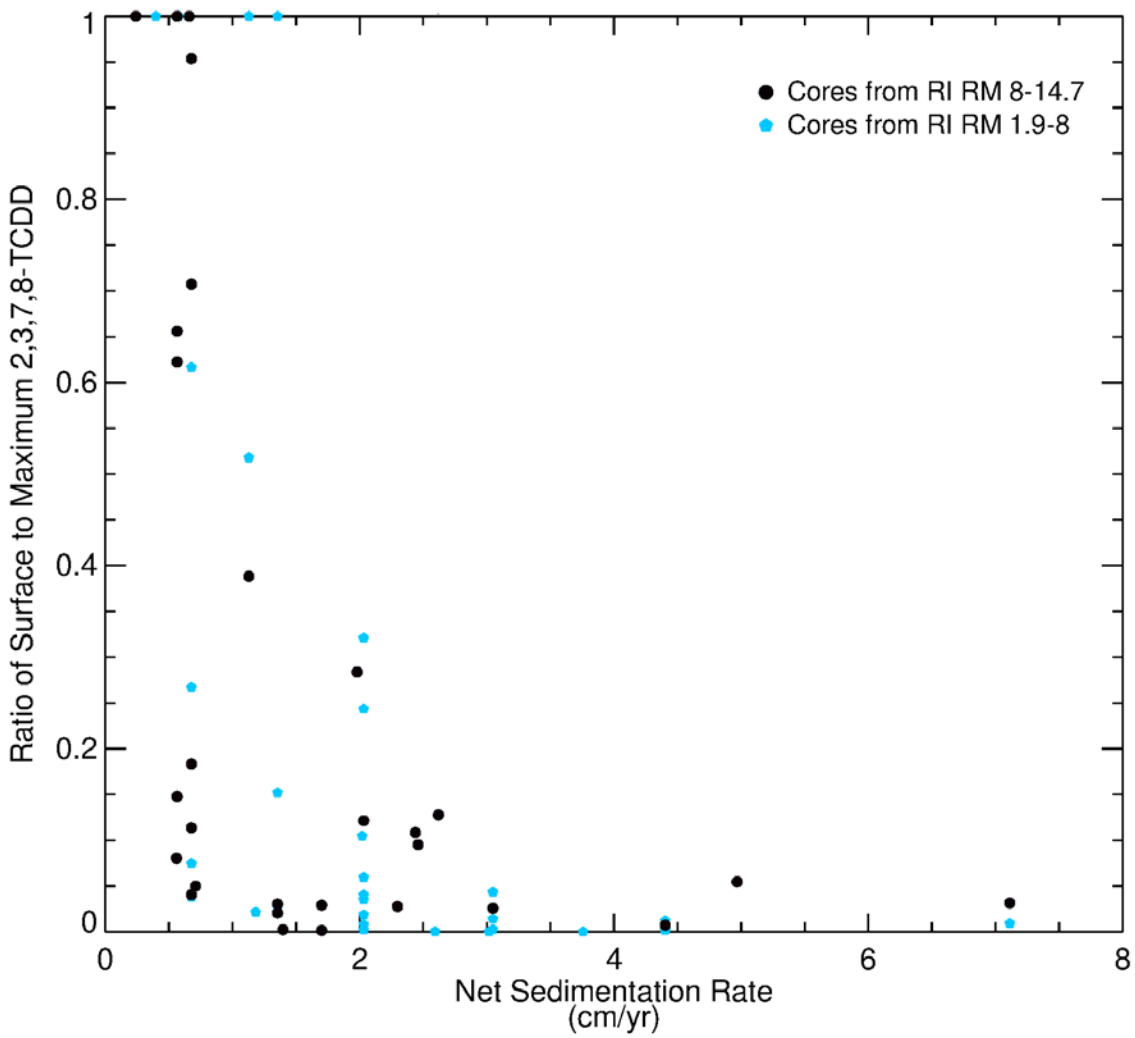
Plots include all post-2005 data with bottom depths less than 6 inches.
Non-detects (NDs) plotted with open symbols at 1/2 the Detection limit (DL). Dashed lines indicate RI reach boundaries.
Excluded samples are without % fines data.
River Miles in RI RM system, which differs from the USACE RM system (used in this IR FS) by about 0.2 to 0.3 miles.

% Fines
- 0 - 10
- 10 - 20
- 20 - 40
- 40 - 60
- 60 - 100

- Passaic River / Newark Bay Data
- TSI Phase I and II Removal Areas
- Non-Detect

Figure 2-2b.
Total PCB Concentrations in the Surface Sediment of LPR and Newark Bay
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

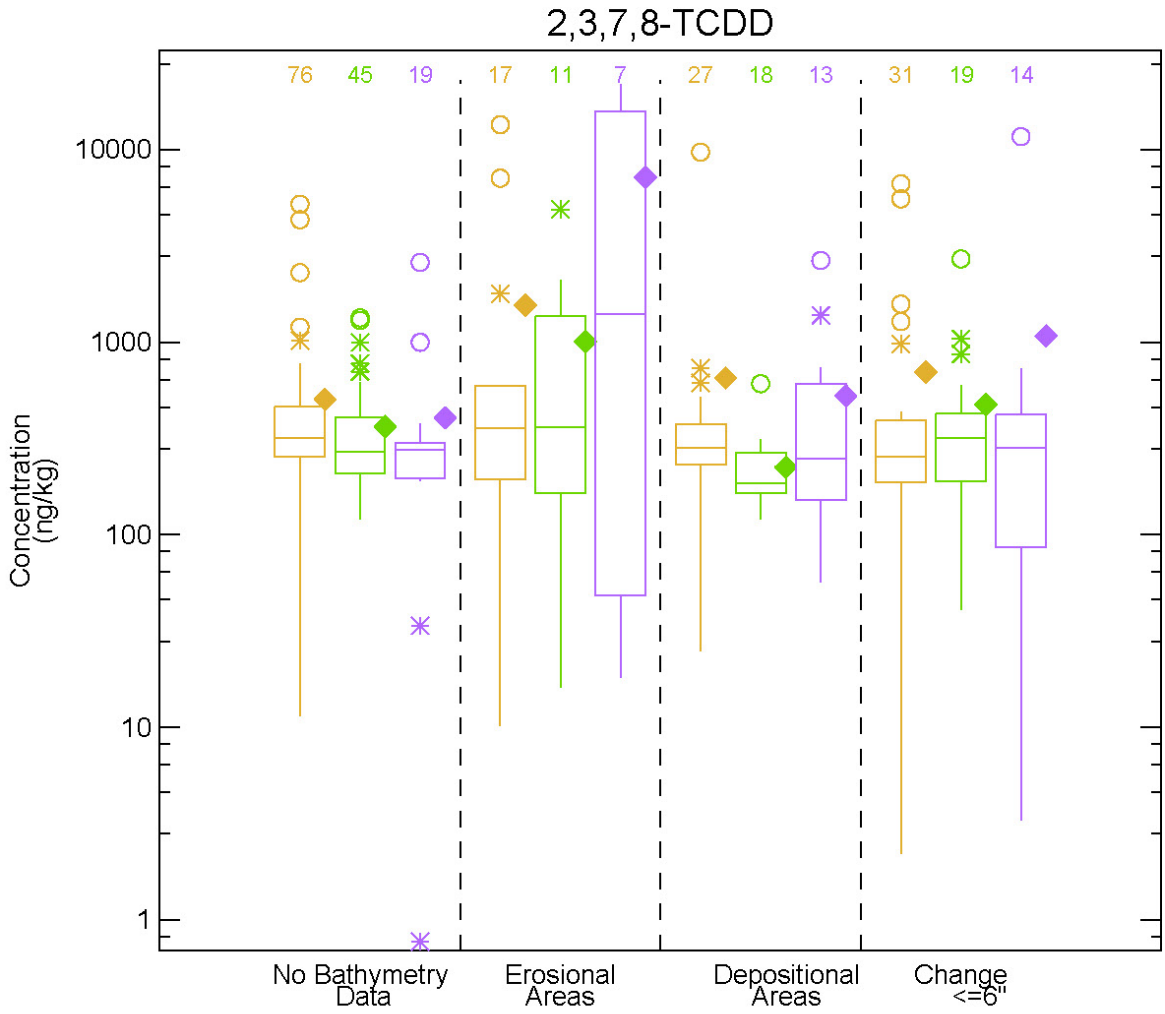
Figure 2-3.
Surface and Subsurface 2,3,7,8-TCDD Concentration over Sediment Type
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Only detected samples plotted.
Surface data use post 2005 data with bottom depths less than 6 inches. Net sedimentation rates estimated from cesium-137 profiles; see RI Appendix I.
Data between RI RM 1.9 and RM 17.4 used in analysis. Data below RM 1.9 not included because of potential impacts of navigational dredging.

Source: AQEA (2019)

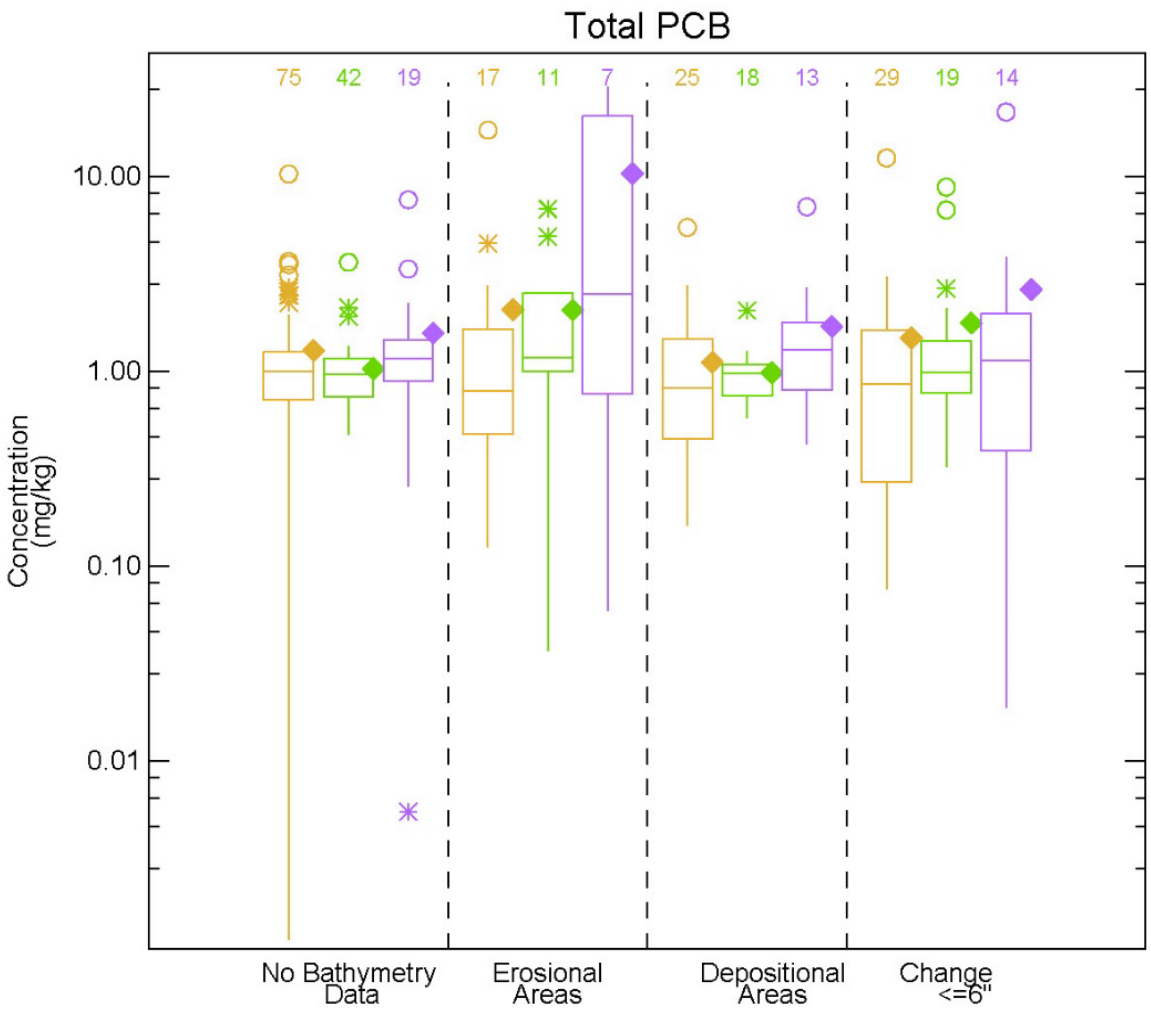
Figure 2-4.
Relationship between Ratio of Surface to Maximum 2,3,7,8-TCDD in Sediment Core and Sedimentation Rate
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Plots include all data from RM 1 to 7 with bottom depths less than 6 inches.
Deposition and erosion defined by bathymetry differences greater than 6 inches between 1995 and 2010.
See Appendix A of the RI Report for a discussion of bathymetric uncertainty.
Filled diamonds indicate the mean of the data. Medians denoted as lines bisecting the box.
Outer outliers are plotted as unfilled circles. Inner outliers are plotted as asterisks.
See RI Section 4, Figure 4.1-5 for more information on Tukey box plots.
River Miles in RI RM system, which differs from the USACE RM system (used in this IR FS) by about 0.2 to 0.3 miles.

- 1995-1999
- 2005-2011 Pre-Irene
- 2011-2013 Post-Irene

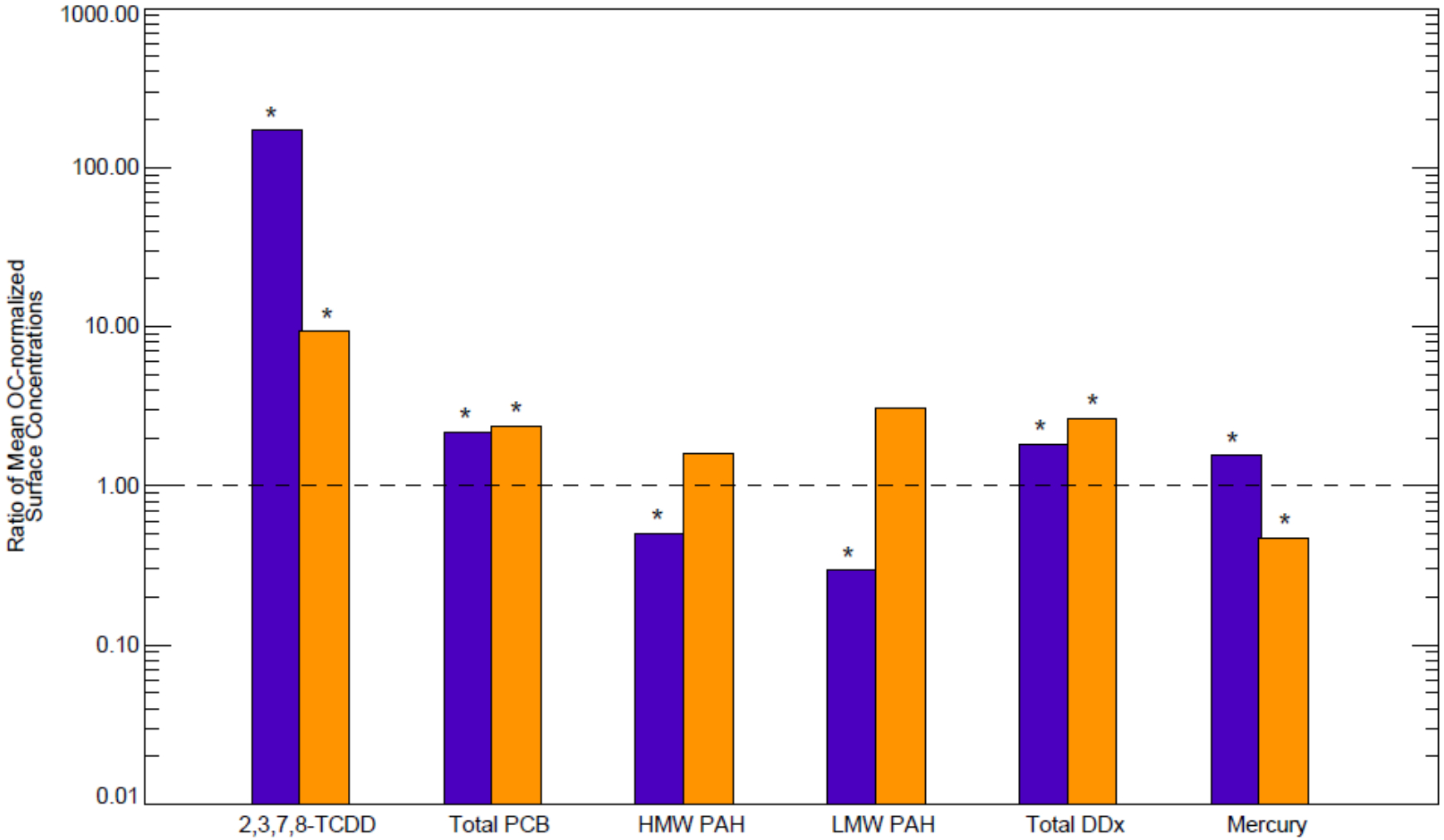
Figure 2-5a.
2,3,7,8-TCDD Concentrations by Bathymetric Category in Surface Sediment: RM 1–7
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Plots include all data from RM 1 to 7 with bottom depths less than 6 inches.
Deposition and erosion defined by bathymetry differences greater than 6 inches between 1995 and 2010.
See Appendix A of the RI Report for a discussion of bathymetric uncertainty.
Filled diamonds indicate the mean of the data. Medians denoted as lines bisecting the box.
Outer outliers are plotted as unfilled circles. Inner outliers are plotted as asterisks.
See RI Section 4, Figure 4.1-5 for more information on Tukey box plots.
River Miles in RI RM system, which differs from the USACE RM system (used in this IR FS) by about 0.2 to 0.3 miles.

- 1995-1999
- 2005-2011 Pre-Irene
- 2011-2013 Post-Irene

Figure 2-5b.
Total PCB Concentrations by Bathymetric Category in Surface Sediment: RM 1–7
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



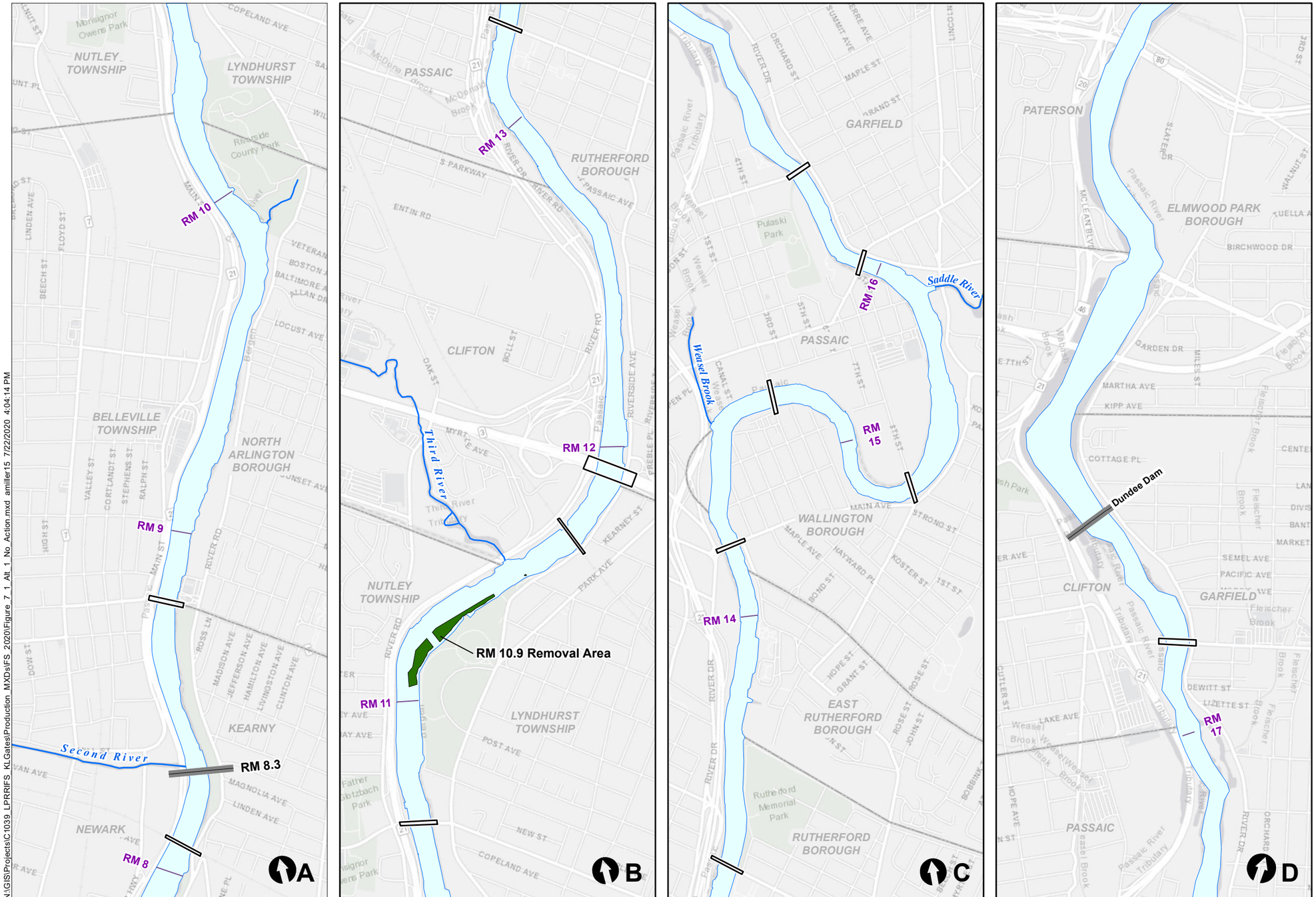
ND samples have been removed.
Upper Newark Bay extends from RM 0 to RM -3.
OC normalized - Organic carbon normalized concentrations. Chemical concentrations are divided by the total organic carbon of the sample.

Source: AQEA (2019)

– – COPC Ratio of 1
* Ratios are statistically different from 1 (Unequal Variances t-test, linear data)

■ Lower 12 miles of LPR/Above Dundee Dam
■ Lower 12 miles of LPR/Upper Newark Bay

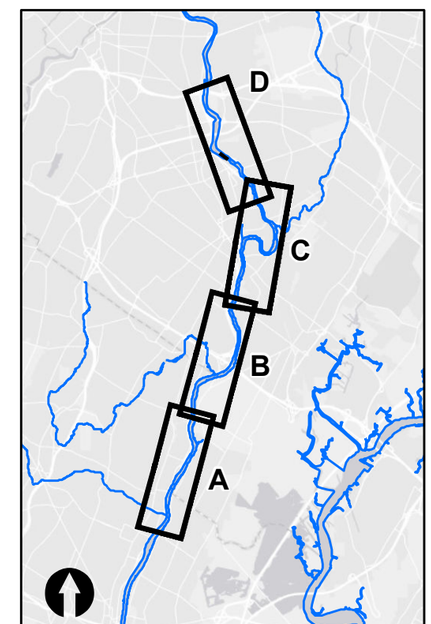
Figure 2-6.
Ratios of Mean Contaminant Levels in Surface Sediment in LPR and Nearby Regions
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Upper 9-Mile Study Area Boundary
Lower Passaic River
River Mile (USACE)
Municipal Boundary
Bridge

Note: River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

Alternative 1 Remedy Elements:
- No further action
- Current institutional controls



0 750 1,500
Feet

Figure 7-1.
Alternative 1 Footprint: No Action
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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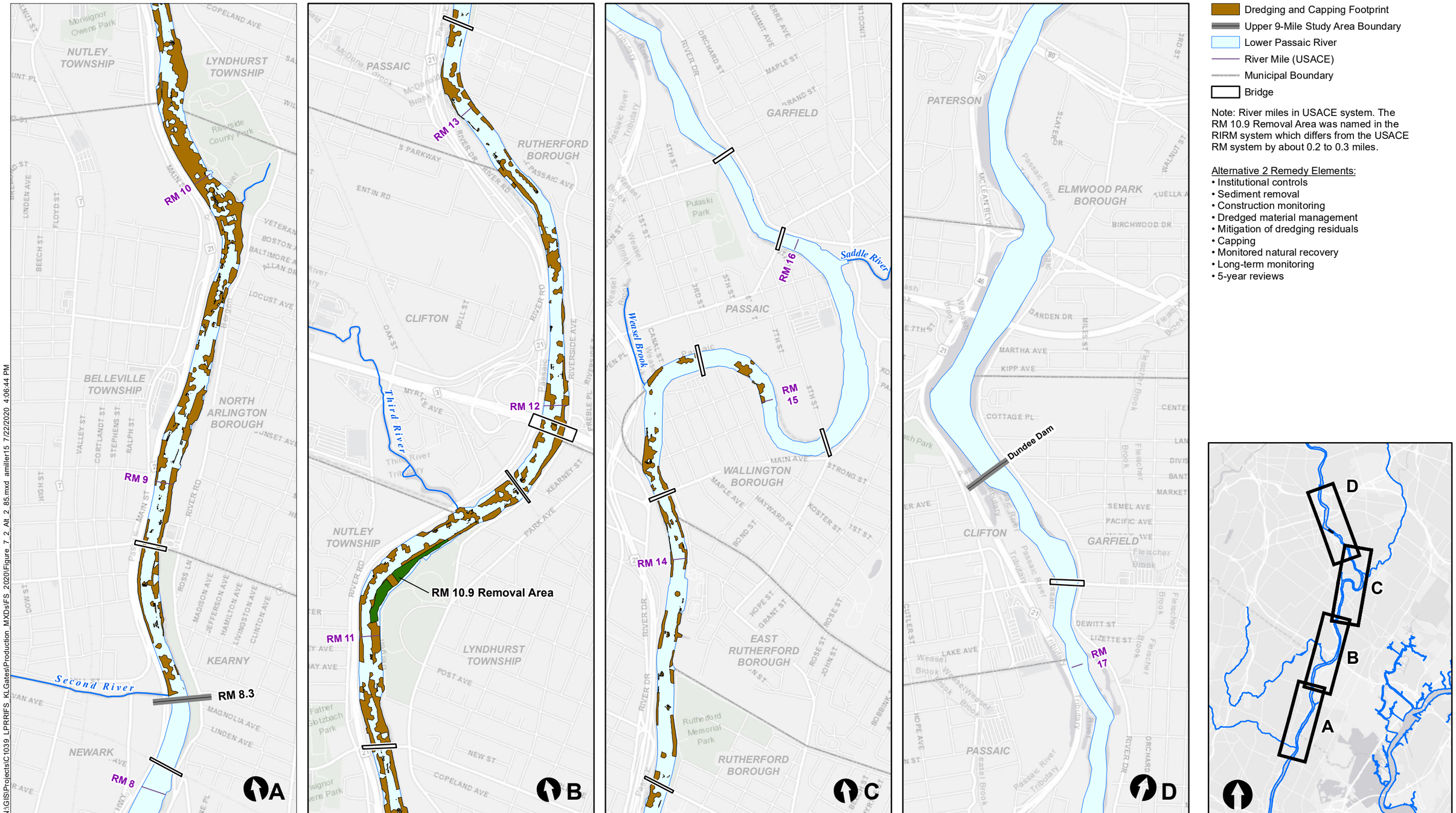

Figure 7-2.
Alternative 2 Footprint:
2,3,7,8-TCDD Target SWAC = 85 ng/kg,
Total PCB RAL = 1 mg/kg
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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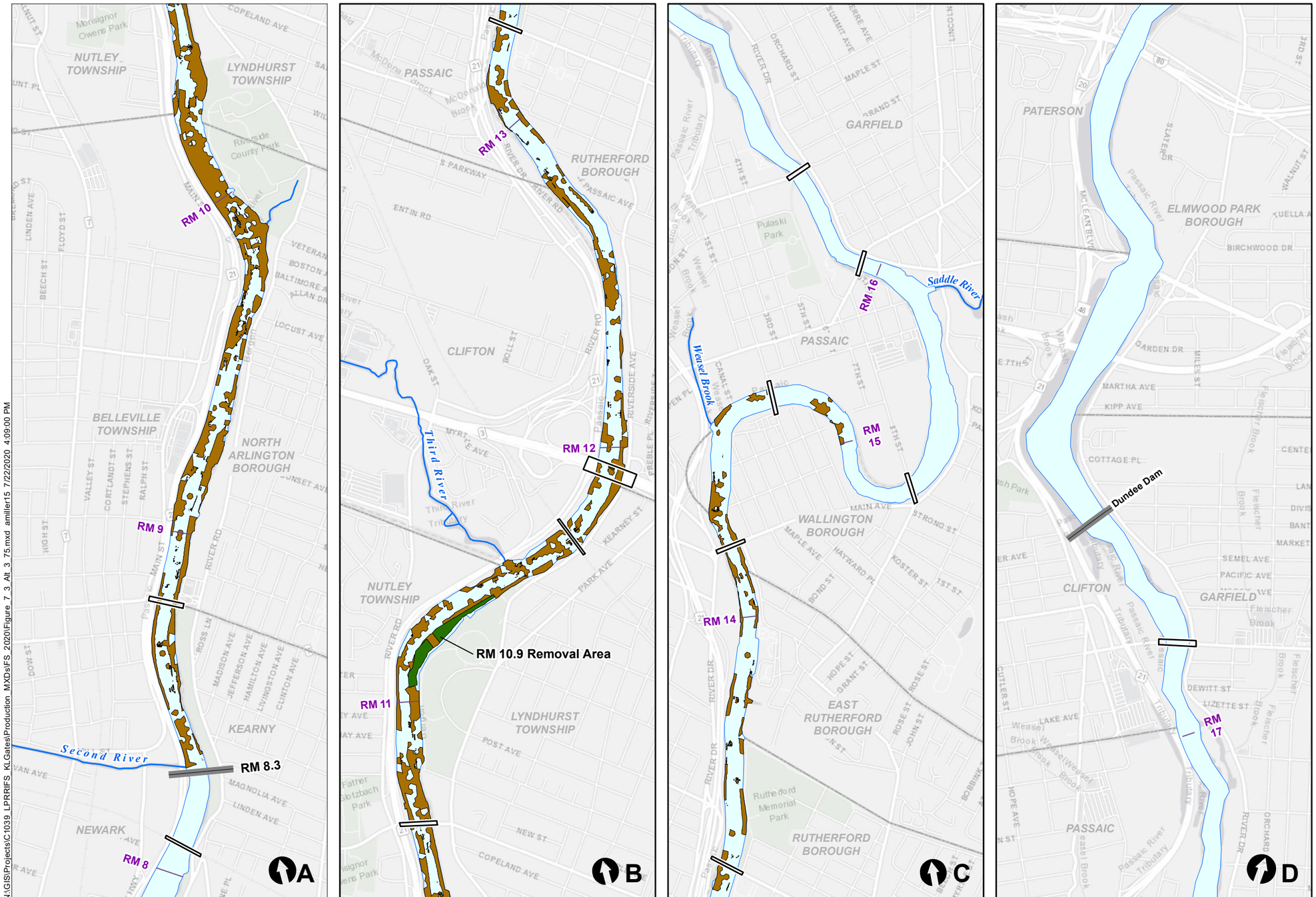
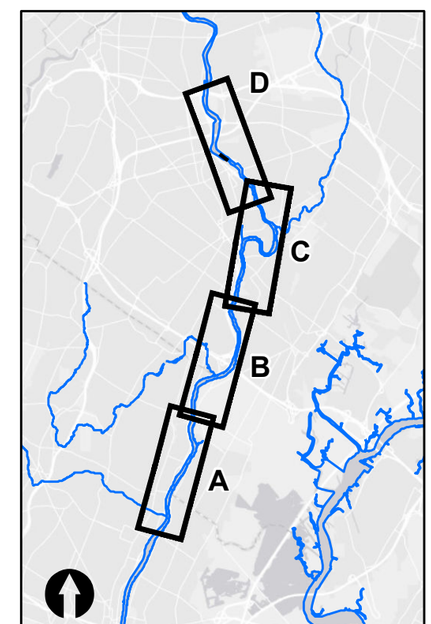


Dredging and Capping Footprint
Upper 9-Mile Study Area Boundary
Lower Passaic River
River Mile (USACE)
Municipal Boundary
Bridge

Note: River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

Alternative 3 Remedy Elements:
- Institutional controls
- Sediment removal
- Construction monitoring
- Dredged material management
- Mitigation of dredging residuals
- Capping
- Monitored natural recovery
- Long-term monitoring
- 5-year reviews



0 750 1,500
Feet

Figure 7-3.
Alternative 3 Footprint:
2,3,7,8-TCDD Target SWAC = 75 ng/kg,
Total PCB RAL = 1 mg/kg
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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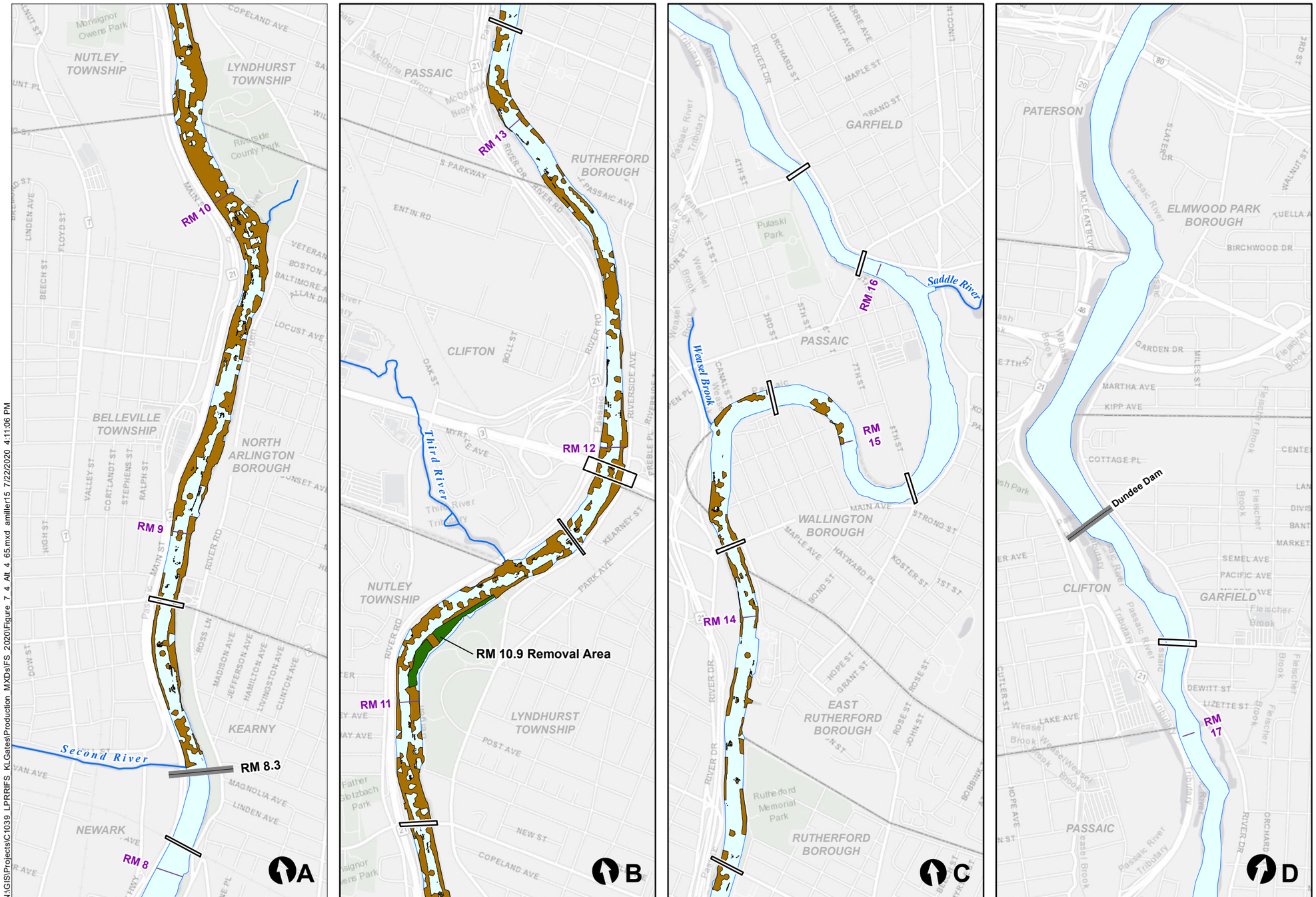
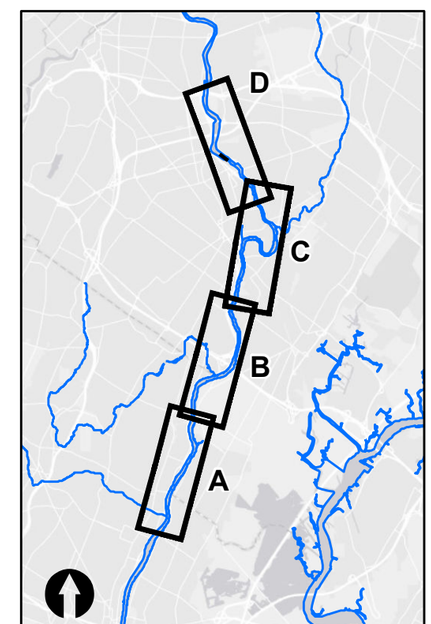


Dredging and Capping Footprint
Upper 9-Mile Study Area Boundary
Lower Passaic River
River Mile (USACE)
Municipal Boundary
Bridge

Note: River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

Alternative 4 Remedy Elements:
- Institutional controls
- Sediment removal
- Construction monitoring
- Dredged material management
- Mitigation of dredging residuals
- Capping
- Monitored natural recovery
- Long-term monitoring
- 5-year reviews



0 750 1,500
Feet

Figure 7-4.
Alternative 4 Footprint:
2,3,7,8-TCDD Target SWAC = 65 ng/kg,
Total PCB RAL = 1 mg/kg
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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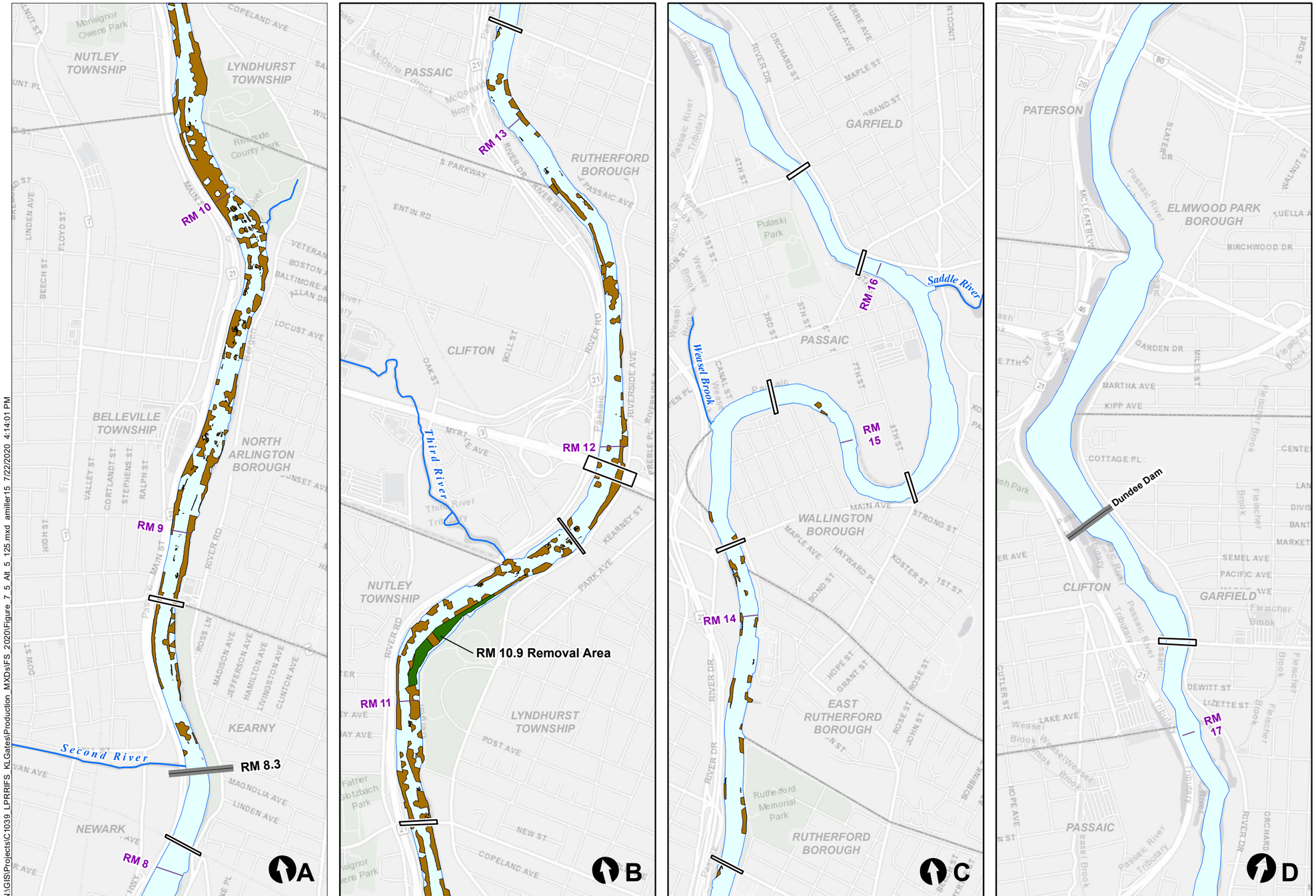
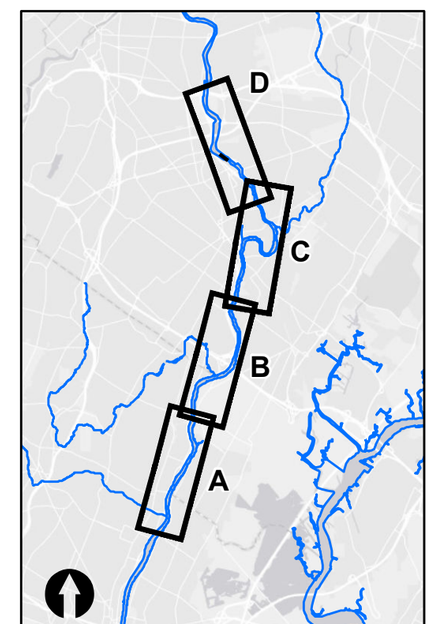


Dredging and Capping Footprint
Upper 9-Mile Study Area Boundary
Lower Passaic River
River Mile (USACE)
Municipal Boundary
Bridge

Note: River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

Alternative 5 Remedy Elements:
- Institutional controls
- Sediment removal
- Construction monitoring
- Dredged material management
- Mitigation of dredging residuals
- Capping
- Monitored natural recovery
- Long-term monitoring
- 5-year reviews



0 750 1,500
Feet

Figure 7-5.
Alternative 5 Footprint:
2,3,7,8-TCDD Target SWAC = 125 ng/kg
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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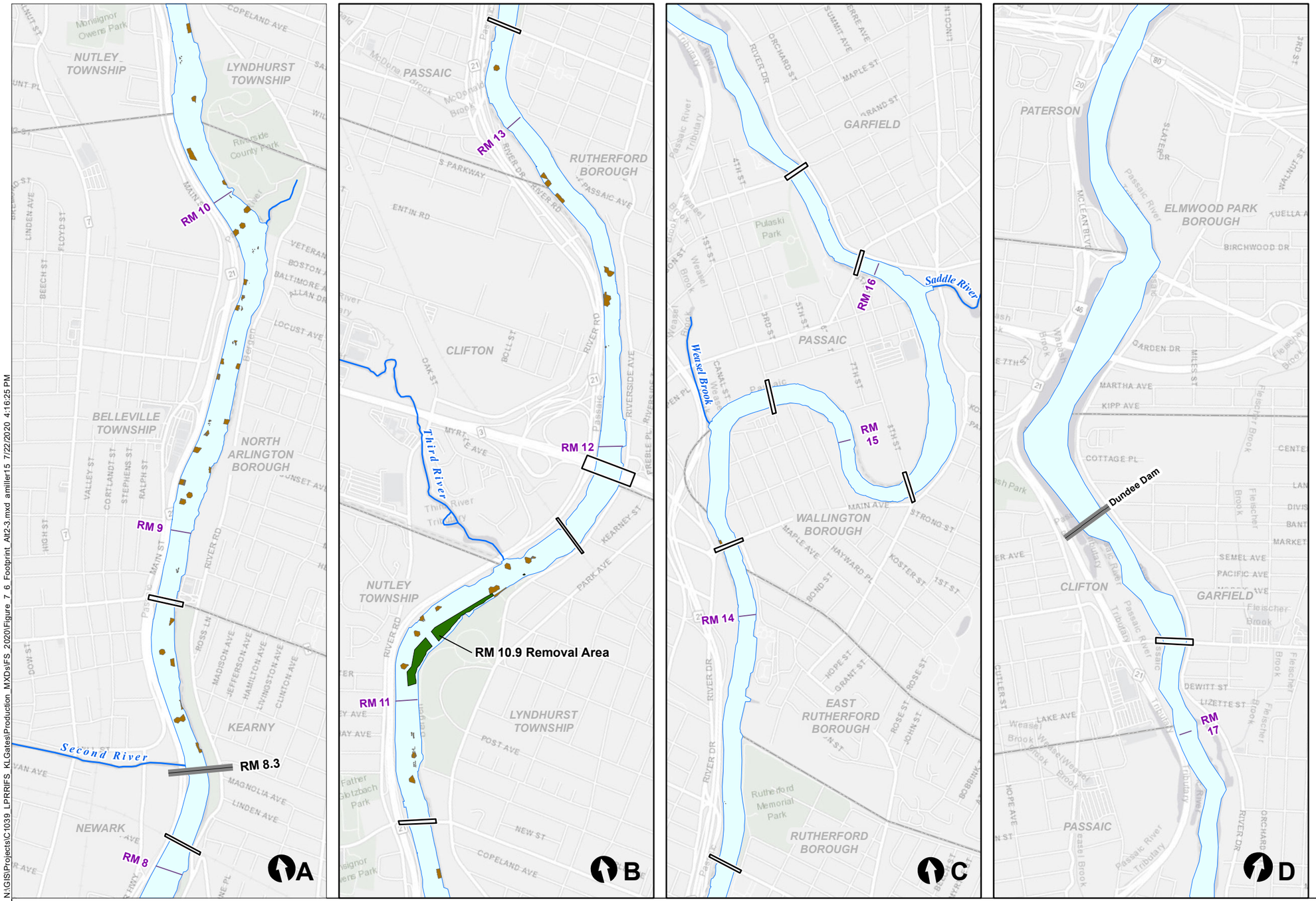
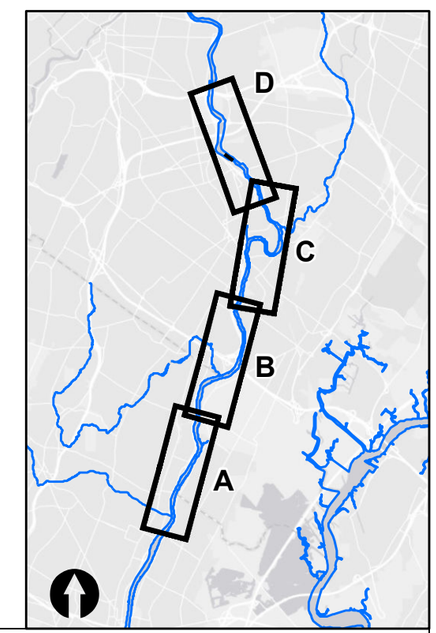


Additional Footprint
Upper 9-Mile Study Area Boundary
Lower Passaic River
River Mile (USACE)
Municipal Boundary
Bridge

Note: River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.



0 750 1,500
Feet

Figure 7-6.
Additional Footprint between Alternative 2 and Alternative 3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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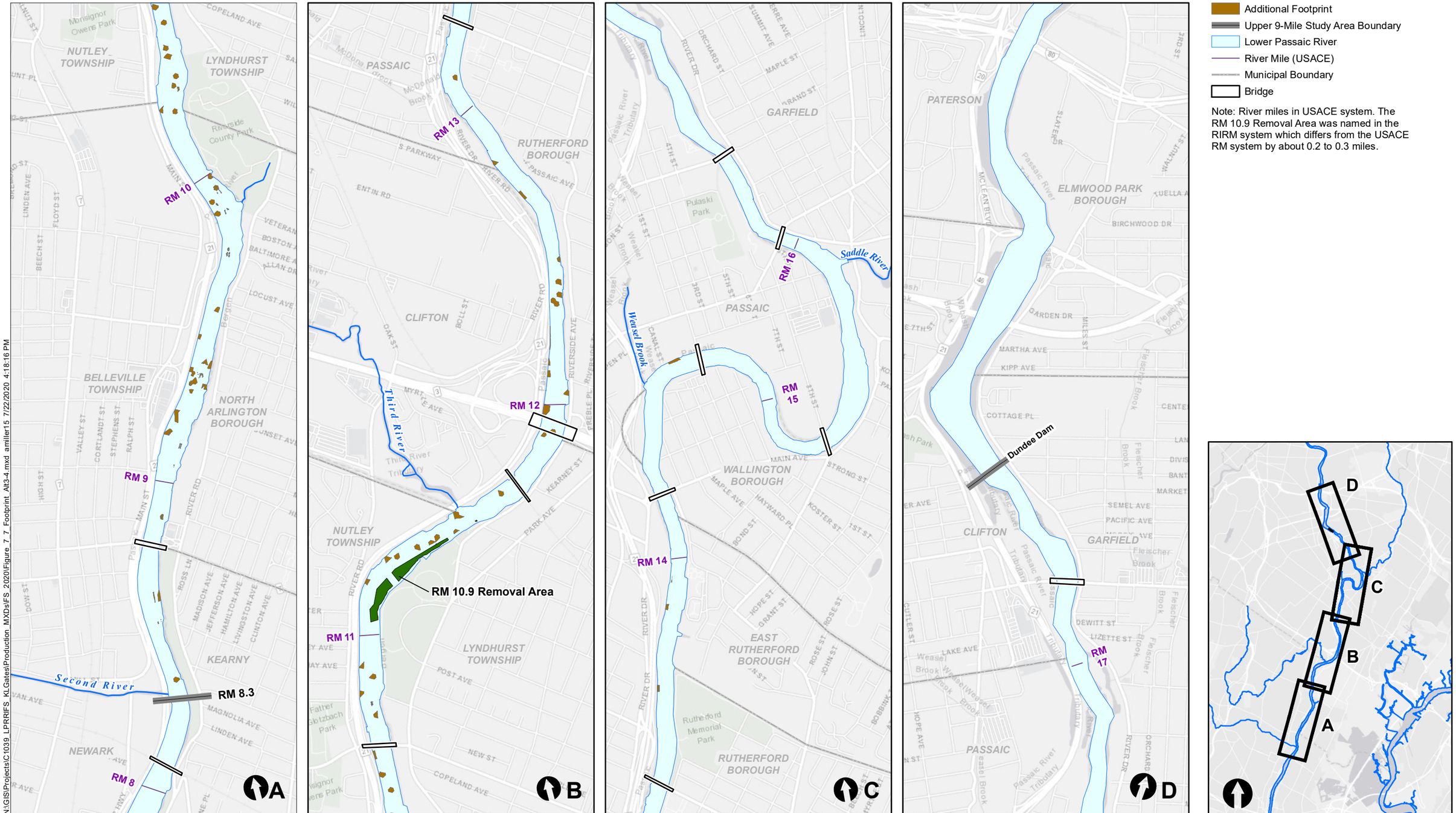

Figure 7-7.
Additional Footprint between Alternative 3 and Alternative 4
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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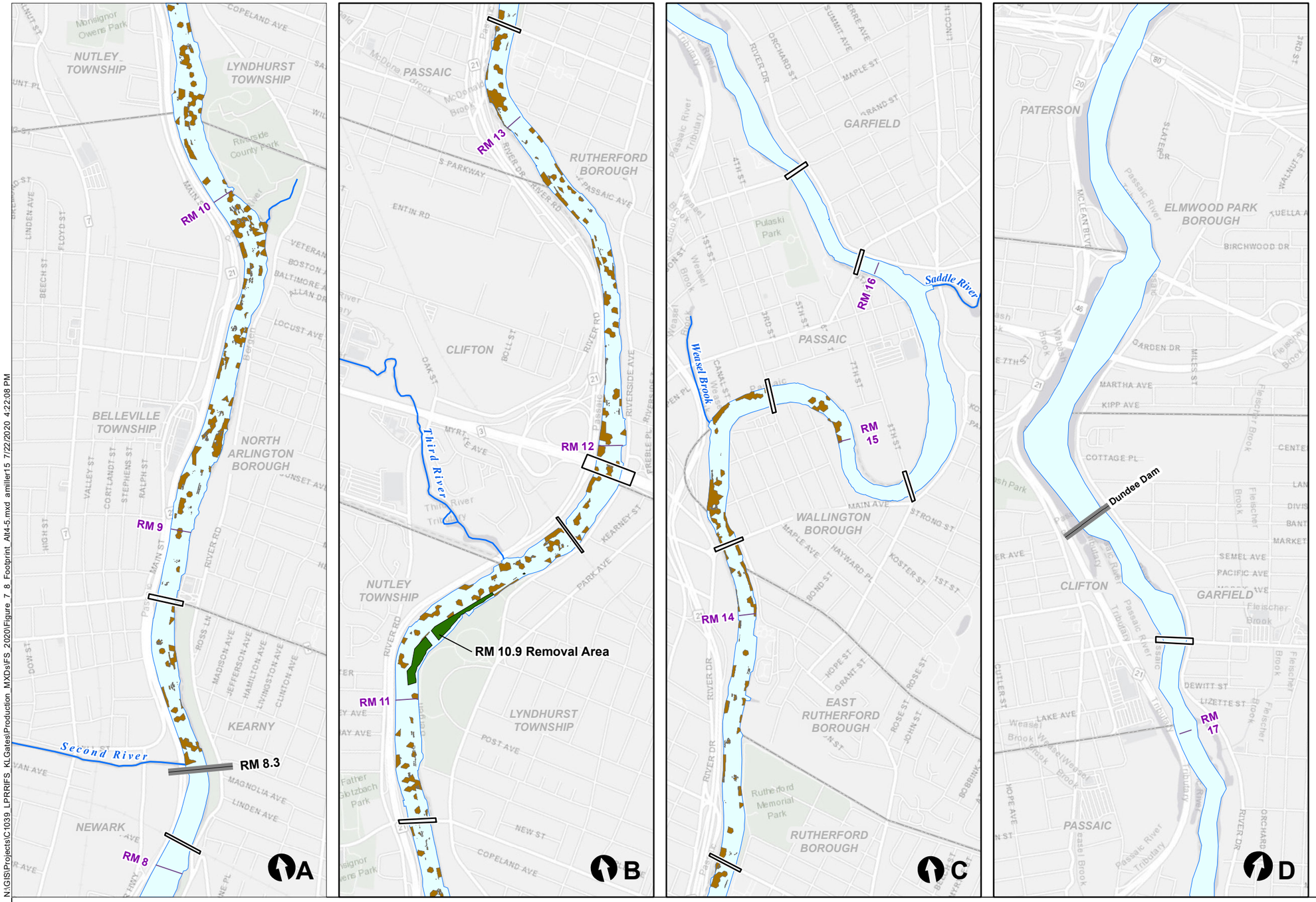
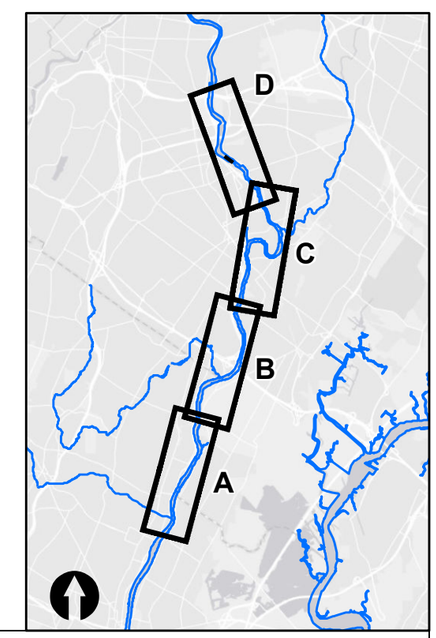


Decreased Footprint
Upper 9-Mile Study Area Boundary
Lower Passaic River
River Mile (USACE)
Municipal Boundary
Bridge

Note: River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.



0 750 1,500
Feet

Figure 7-8.
Decreased Footprint between Alternative 4 and Alternative 5
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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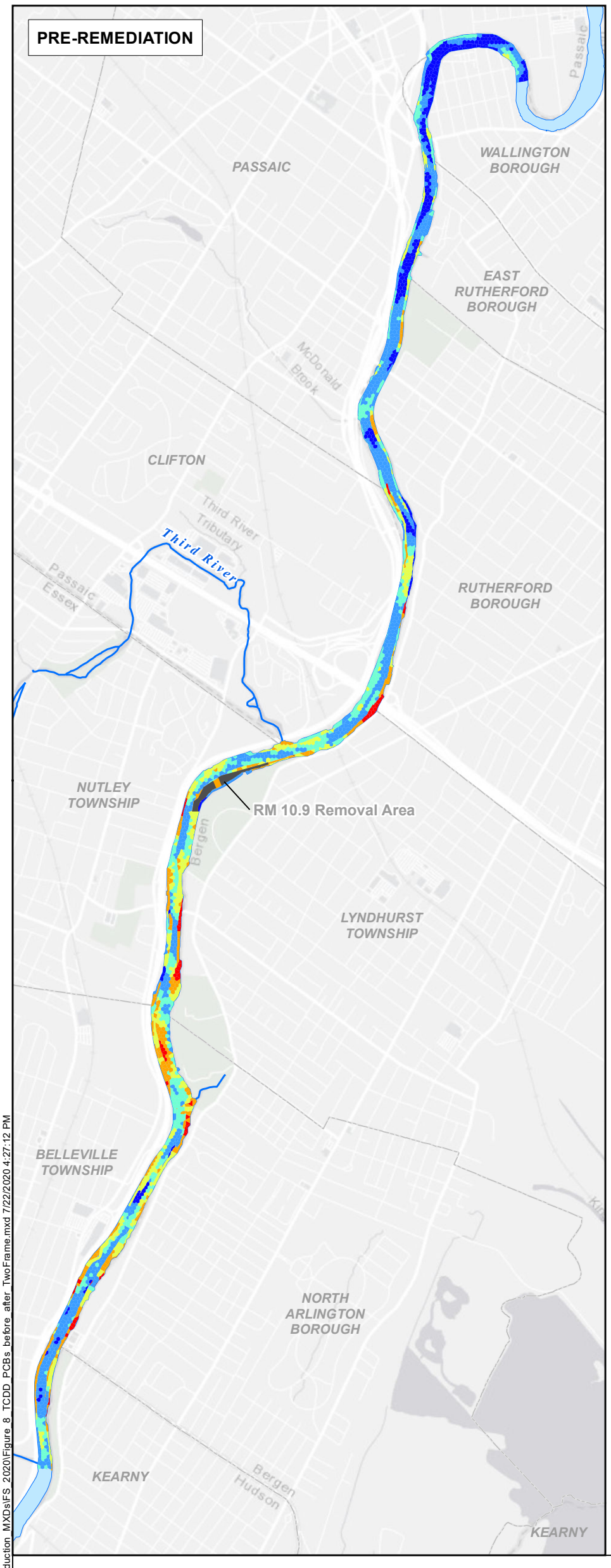

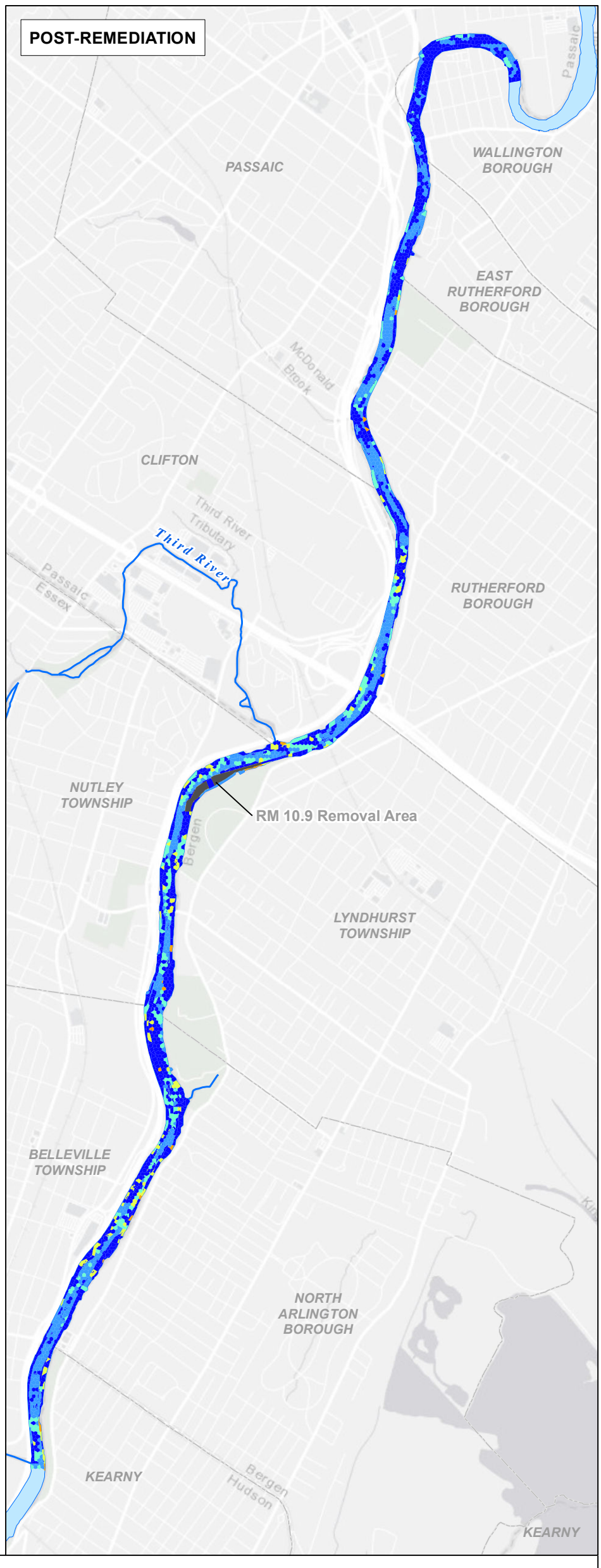

2,3,7,8-TCDD (ng/kg)

- ≤10
- 10-100
- 100-300
- 300-1,000
- 1,000-10,000
- ≥10,000

Pre-Remediation	
Area (ac)	Volume (yd^3)
34	138,000
87	353,000
54	218,000
41	167,000
28	111,000
7	27,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 10 ng/kg for 2,3,7,8-TCDD within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-1a.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of 2,3,7,8-TCDD, Alternative 2
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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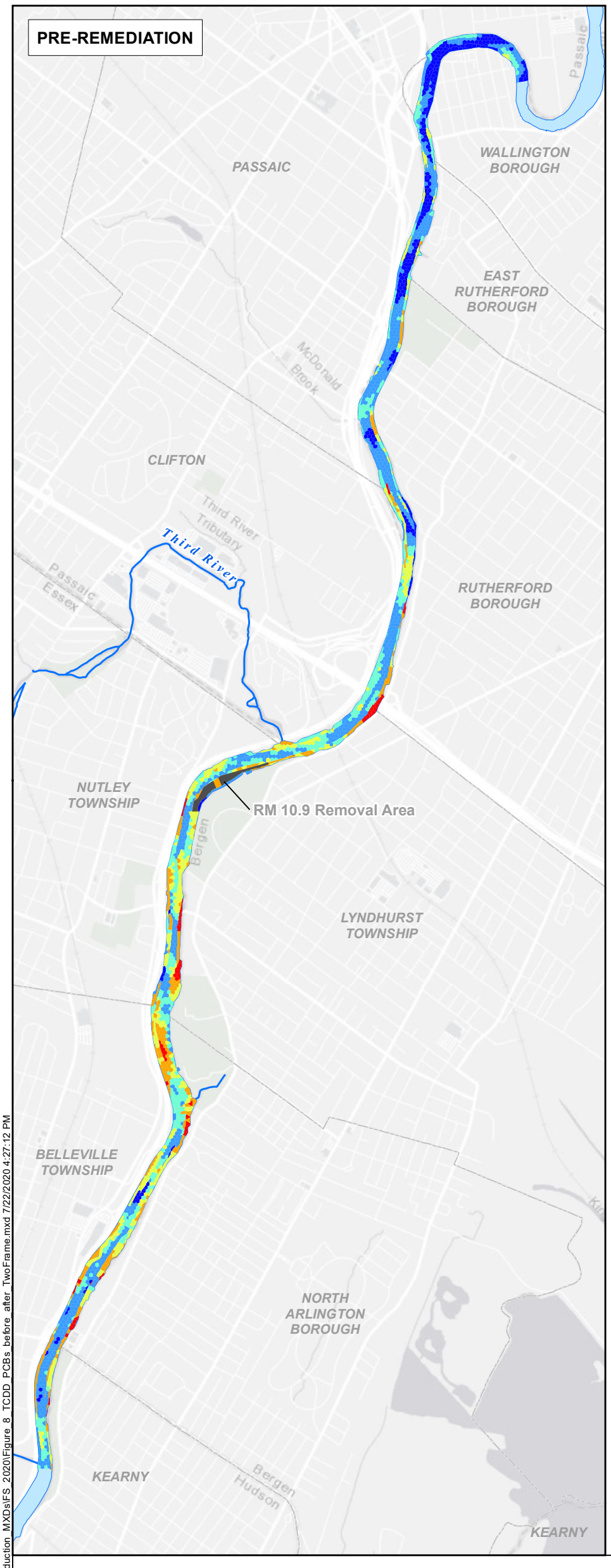

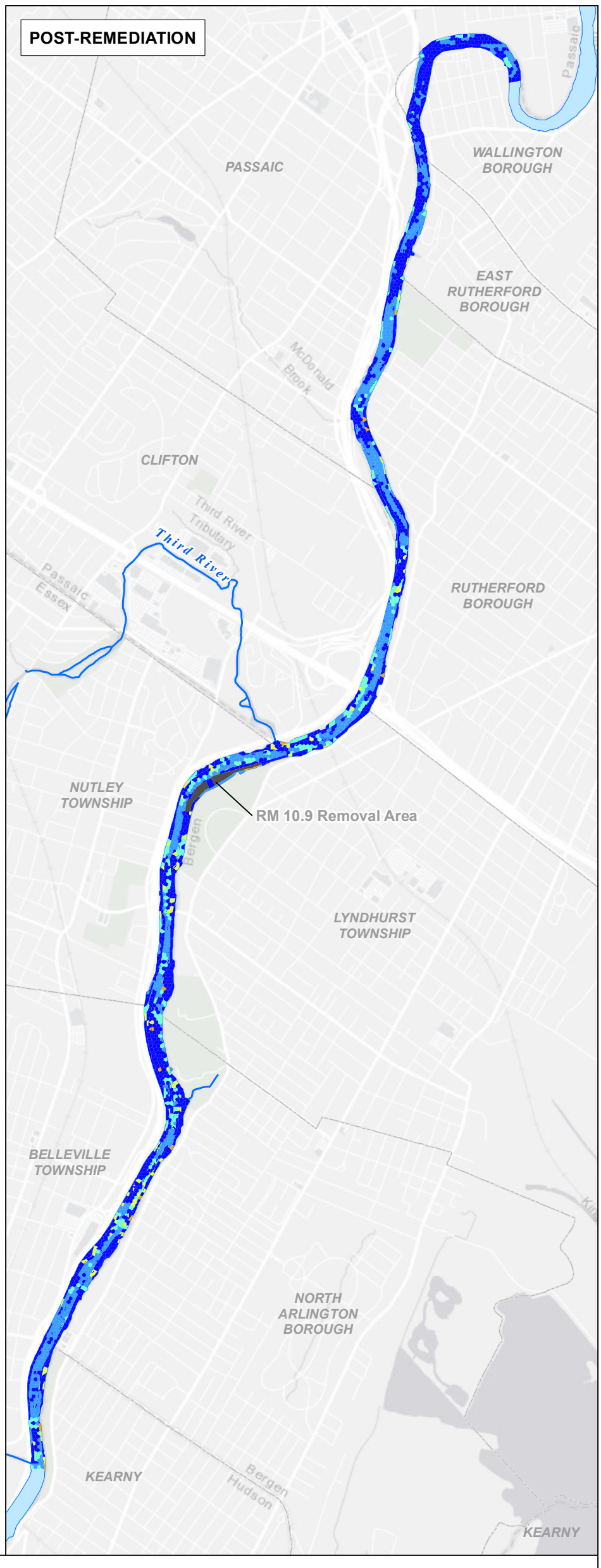

2,3,7,8-TCDD (ng/kg)

- ≤10
- 10-100
- 100-300
- 300-1,000
- 1,000-10,000
- ≥10,000

Pre-Remediation	
Area (ac)	Volume (yd^3)
34	138,000
87	353,000
54	218,000
41	167,000
28	111,000
7	27,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 10 ng/kg for 2,3,7,8-TCDD within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-1b.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of 2,3,7,8-TCDD, Alternative 3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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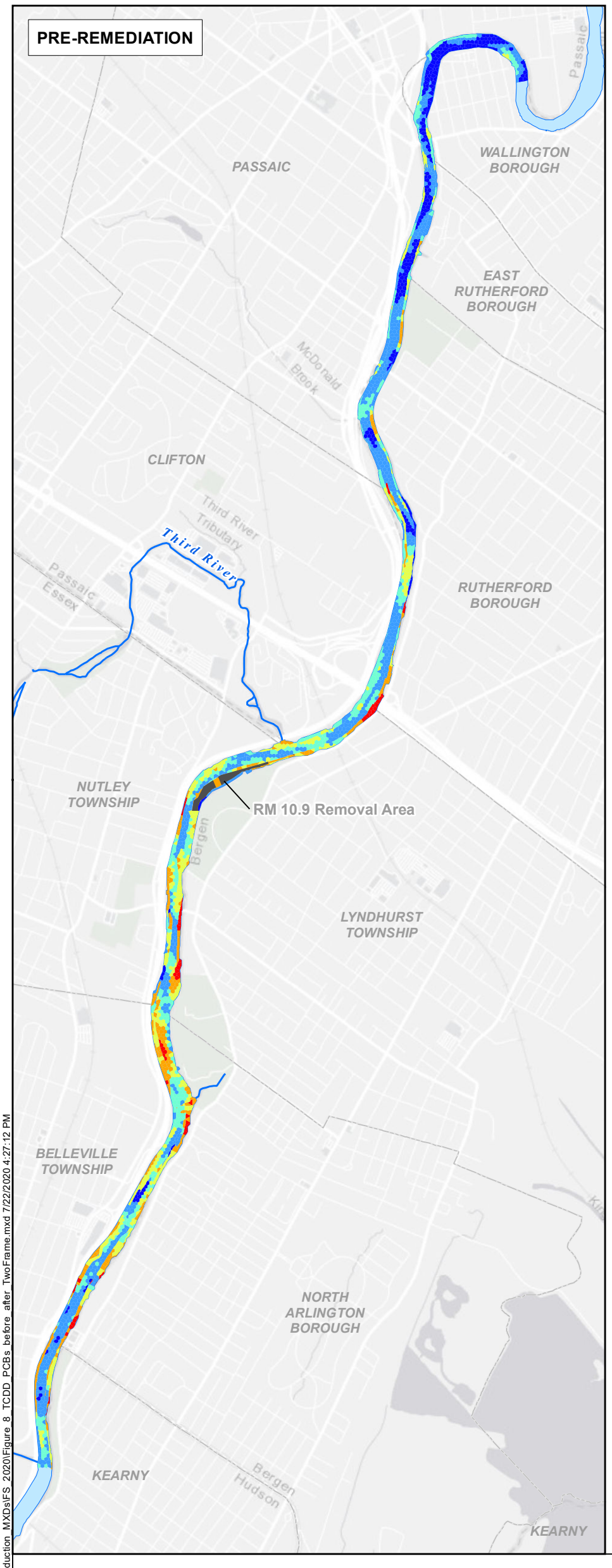

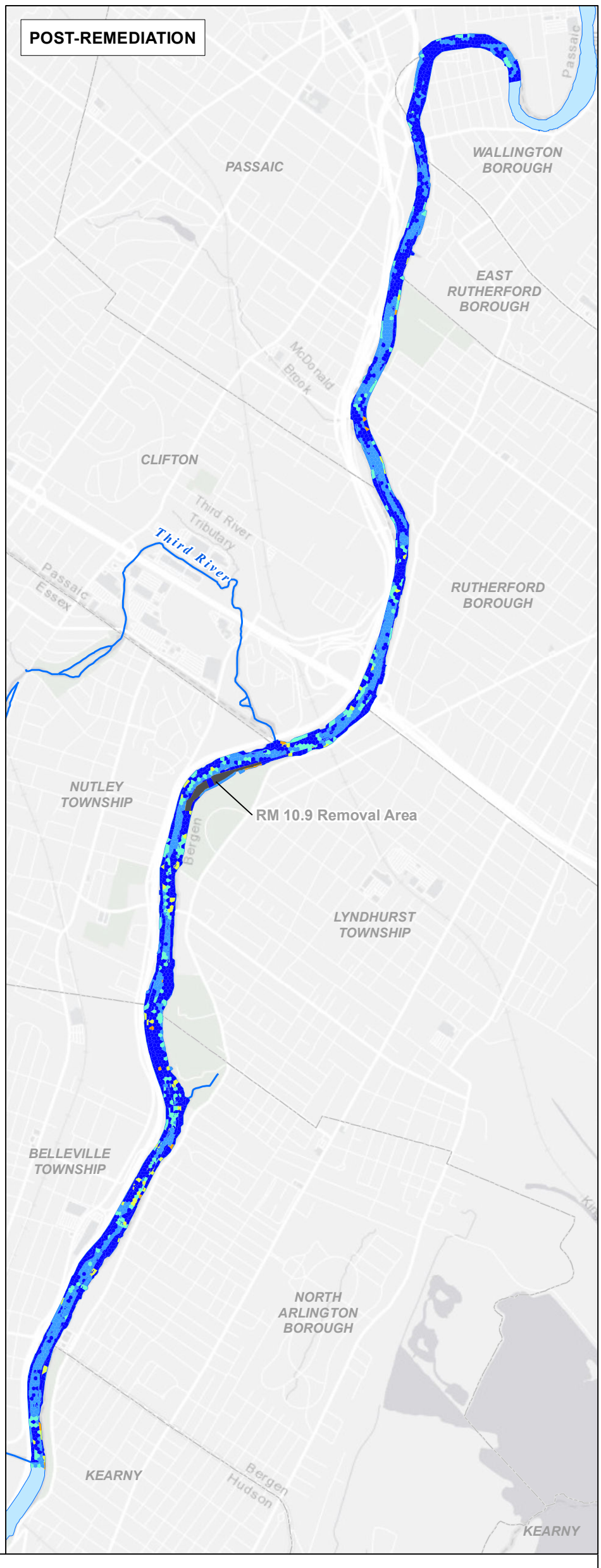

2,3,7,8-TCDD (ng/kg)

- ≤10
- 10-100
- 100-300
- 300-1,000
- 1,000-10,000
- ≥10,000

Pre-Remediation	
Area (ac)	Volume (yd^3)
34	138,000
87	353,000
54	218,000
41	167,000
28	111,000
7	27,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 10 ng/kg for 2,3,7,8-TCDD within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-1c.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of 2,3,7,8-TCDD, Alternative 4
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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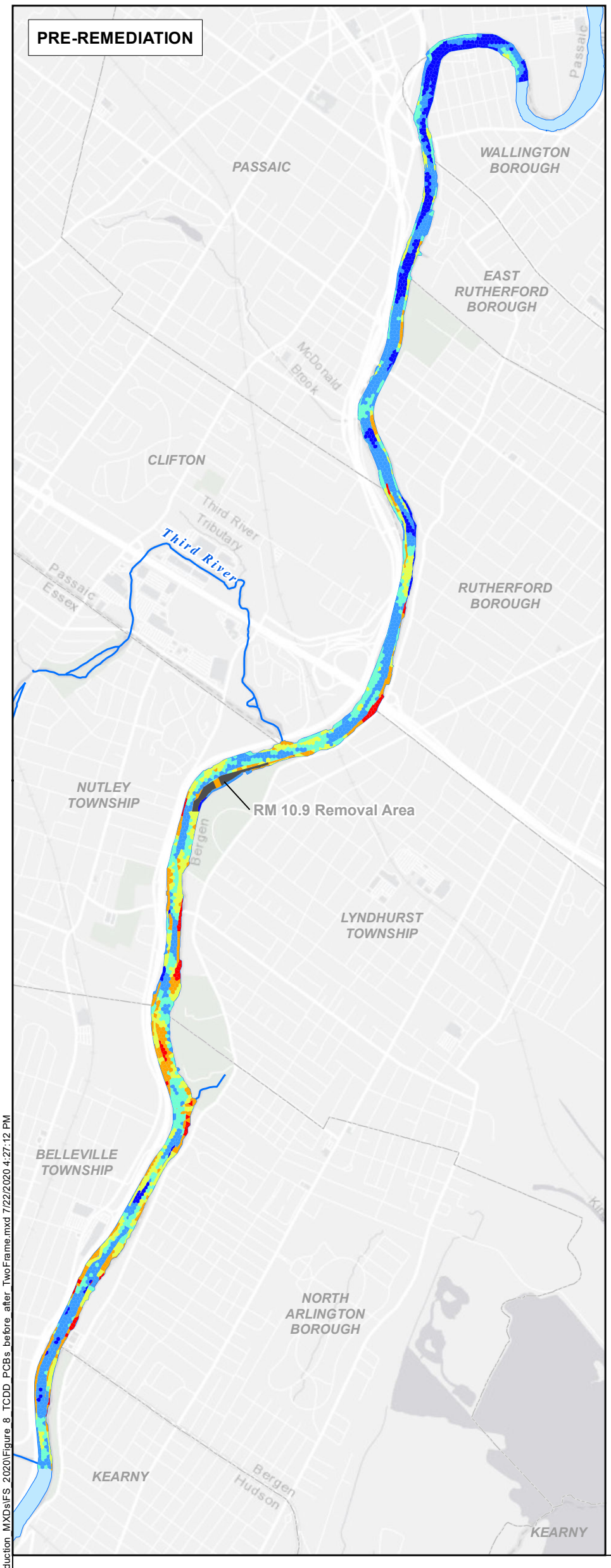

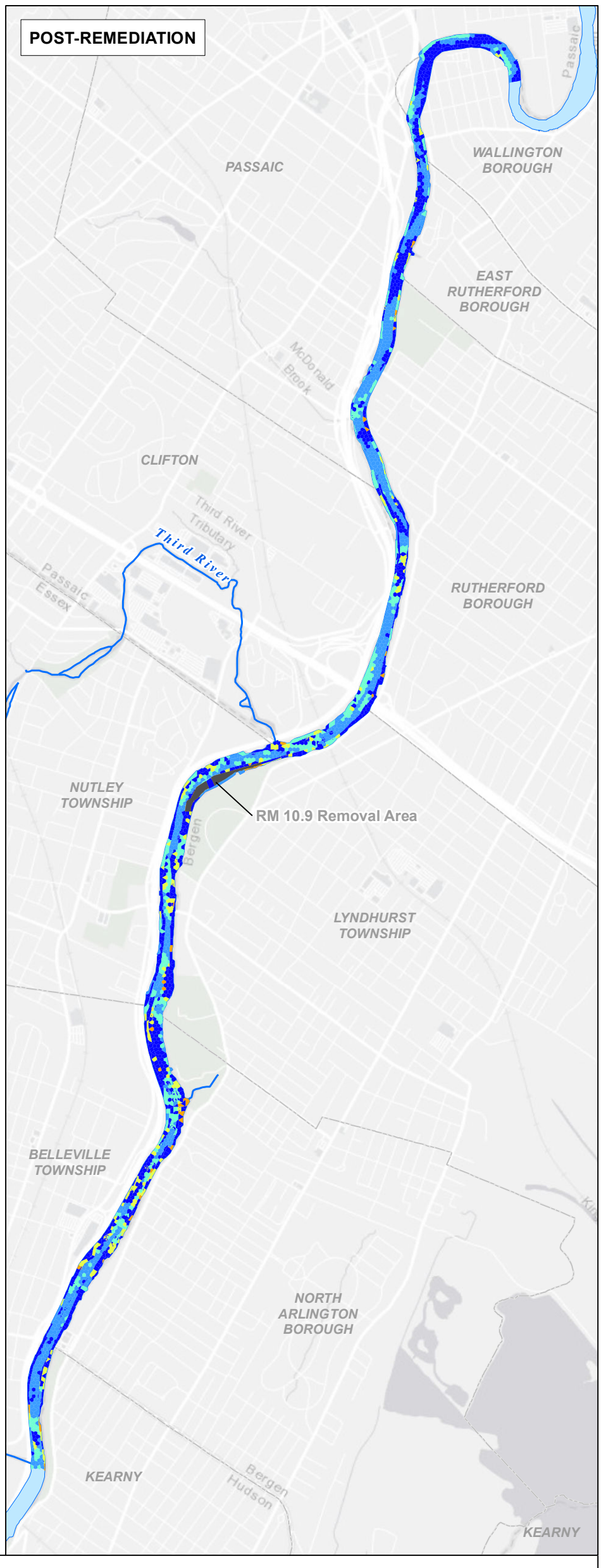

2,3,7,8-TCDD (ng/kg)

- ≤10
- 10-100
- 100-300
- 300-1,000
- 1,000-10,000
- ≥10,000

Pre-Remediation	
Area (ac)	Volume (yd^3)
34	138,000
87	353,000
54	218,000
41	167,000
28	111,000
7	27,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 10 ng/kg for 2,3,7,8-TCDD within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-1d.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of 2,3,7,8-TCDD, Alternative 5
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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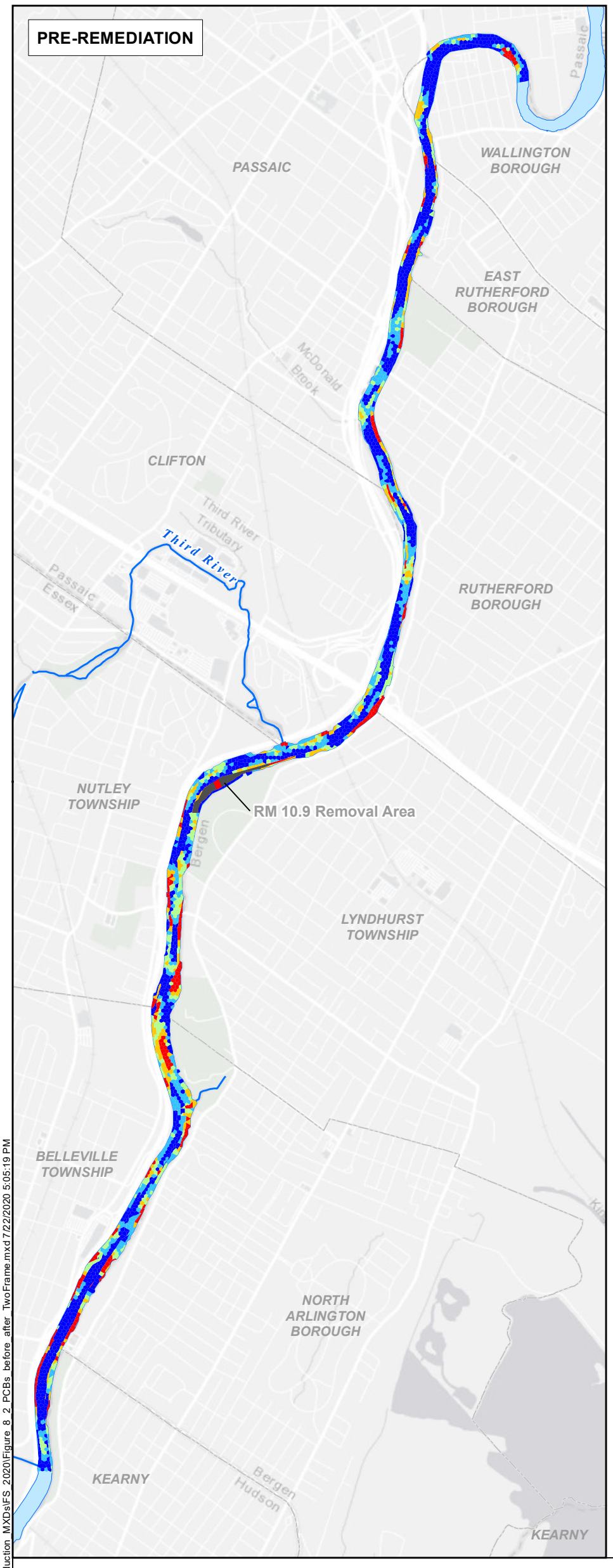

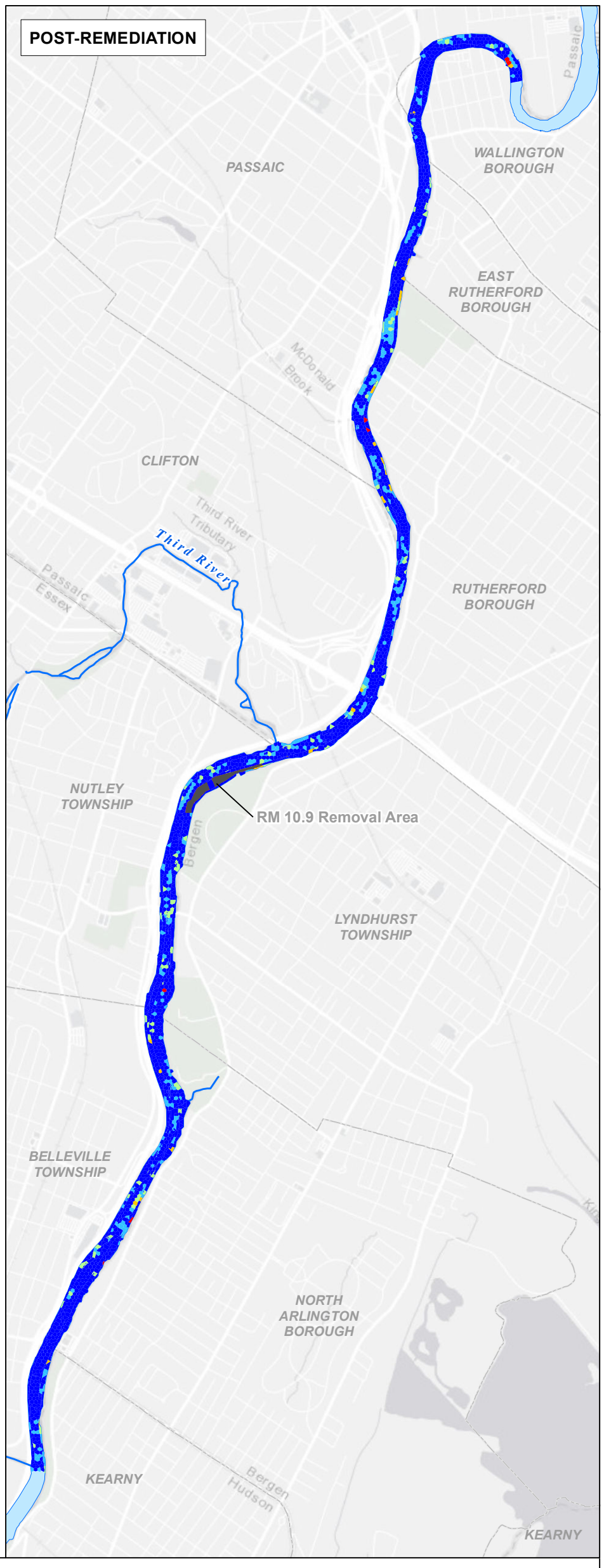

Total PCBs (mg/kg)

- ≤0.5
- 0.5-1
- 1-2
- 2-4
- ≥4

Pre-Remediation	
Area (ac)	Volume (yd^3)
120	484,000
50	202,000
36	143,000
23	93,000
23	91,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 0 mg/kg for Total PCBs within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-2a.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of Total PCBs, Alternative 2
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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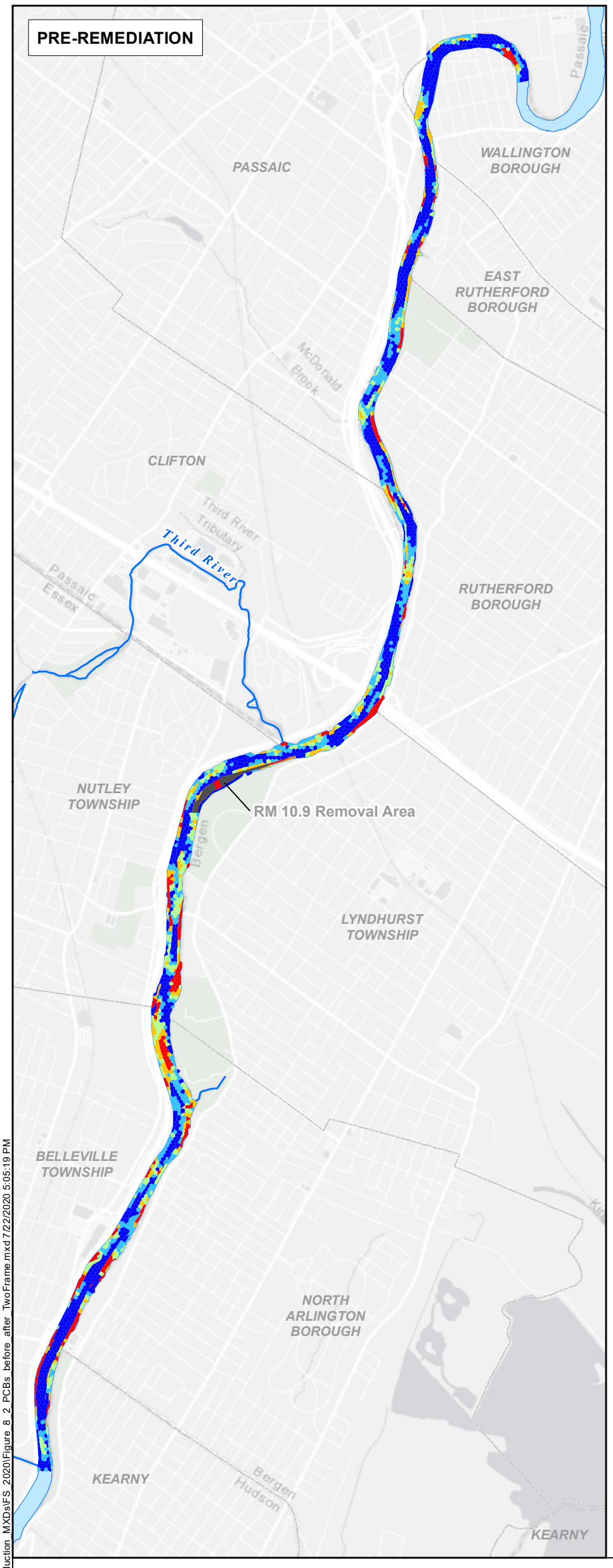

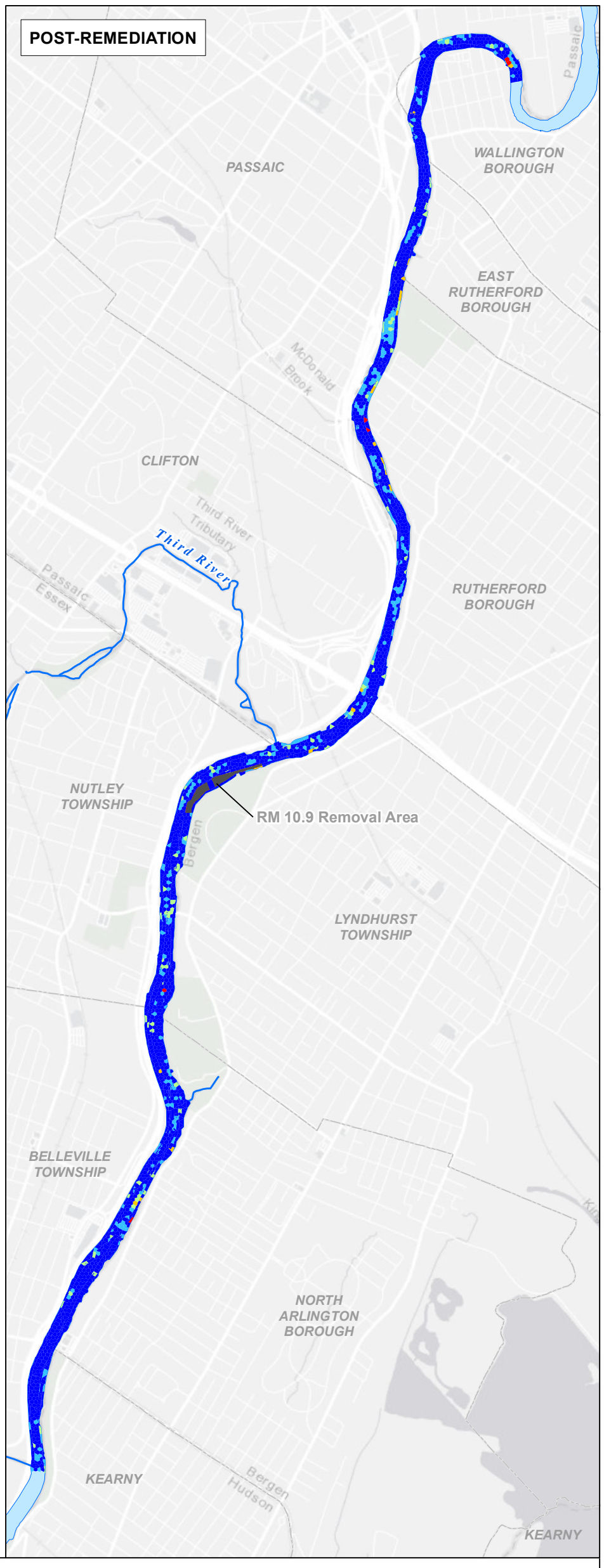

Total PCBs (mg/kg)

- ≤0.5
- 0.5-1
- 1-2
- 2-4
- ≥4

Pre-Remediation	
Area (ac)	Volume (yd^3)
120	484,000
50	202,000
36	143,000
23	93,000
23	91,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 0 mg/kg for Total PCBs within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-2b.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of Total PCBs, Alternative 3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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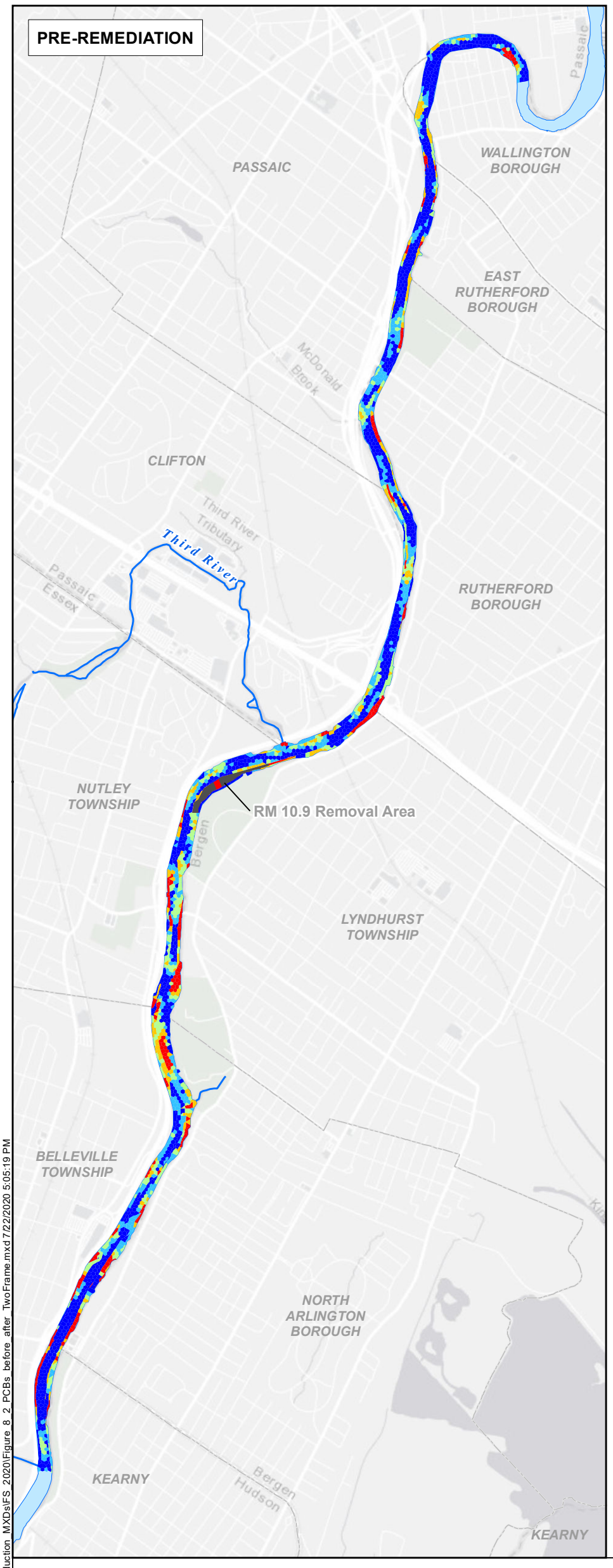

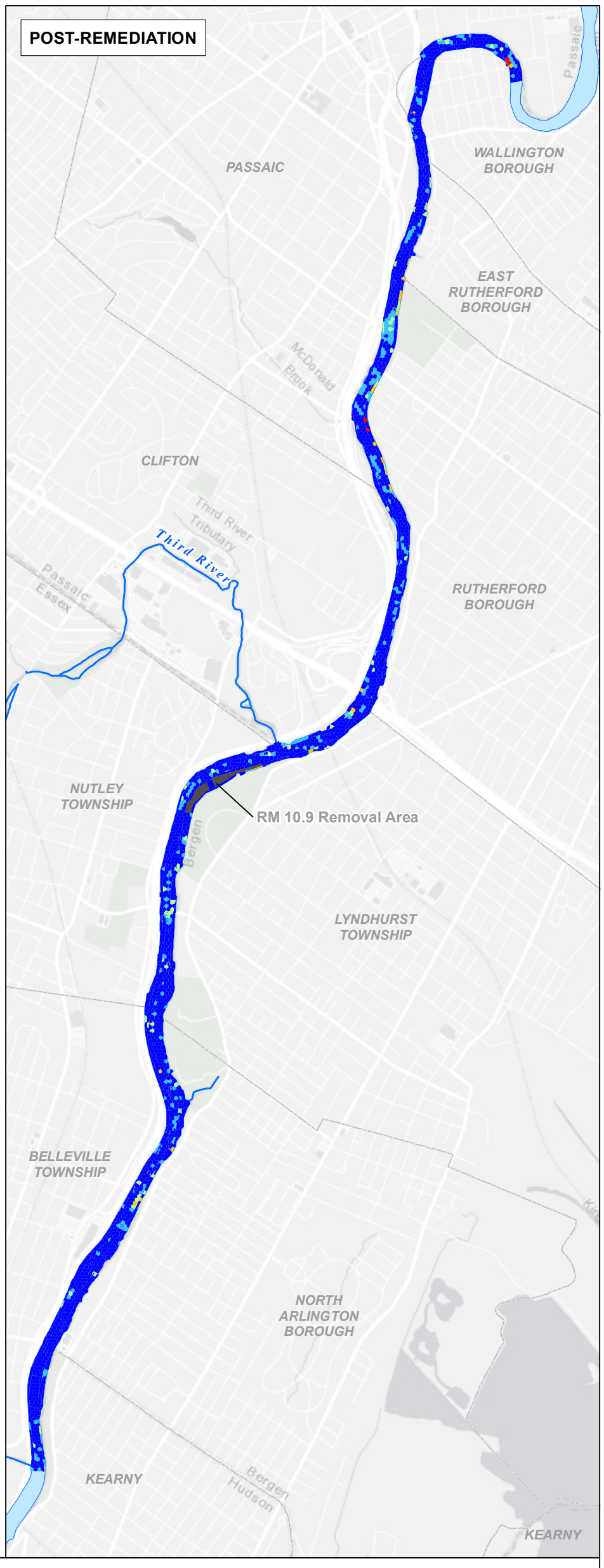

Total PCBs (mg/kg)

- ≤0.5
- 0.5-1
- 1-2
- 2-4
- ≥4

Pre-Remediation	
Area (ac)	Volume (yd^3)
120	484,000
50	202,000
36	143,000
23	93,000
23	91,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 0 mg/kg for Total PCBs within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-2c.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of Total PCBs, Alternative 4
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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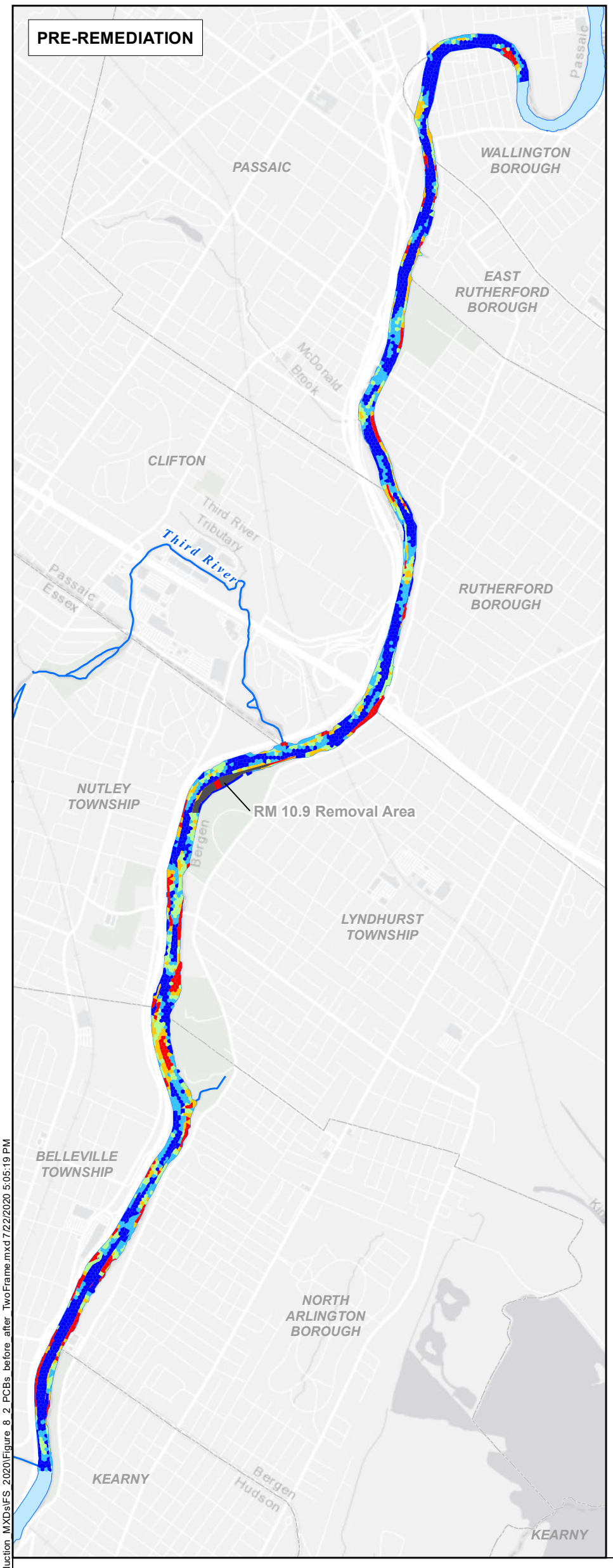

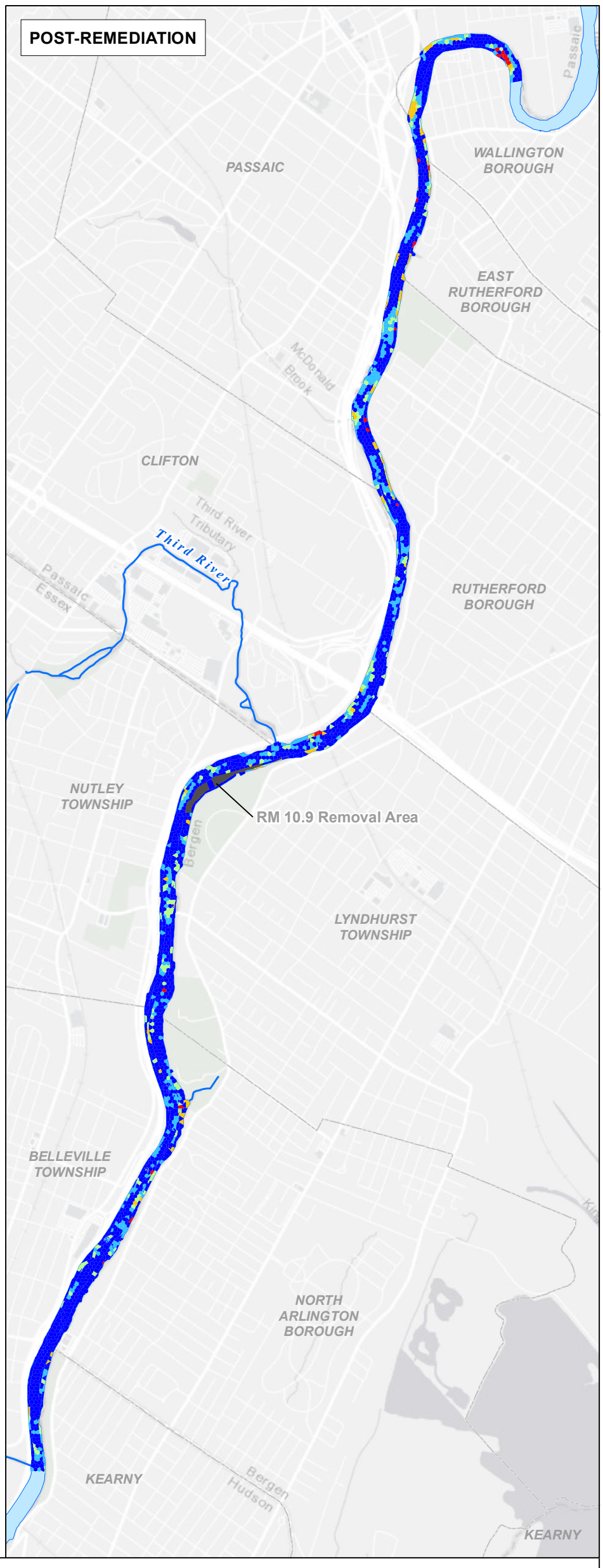

Total PCBs (mg/kg)

- ≤0.5
- 0.5-1
- 1-2
- 2-4
- ≥4

Pre-Remediation	
Area (ac)	Volume (yd^3)
120	484,000
50	202,000
36	143,000
23	93,000
23	91,000

Notes:
1. River miles in USACE system. The RM 10.9 Removal Area was named in the RIRM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

2. Mapped concentrations based on Conditional Simulation 37. The post-remediation concentrations reflect substitution of a replacement value of 0 mg/kg for Total PCBs within the active remedial footprint.

0 1,250 2,500
Feet

Figure 8-2d.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of Total PCBs, Alternative 5
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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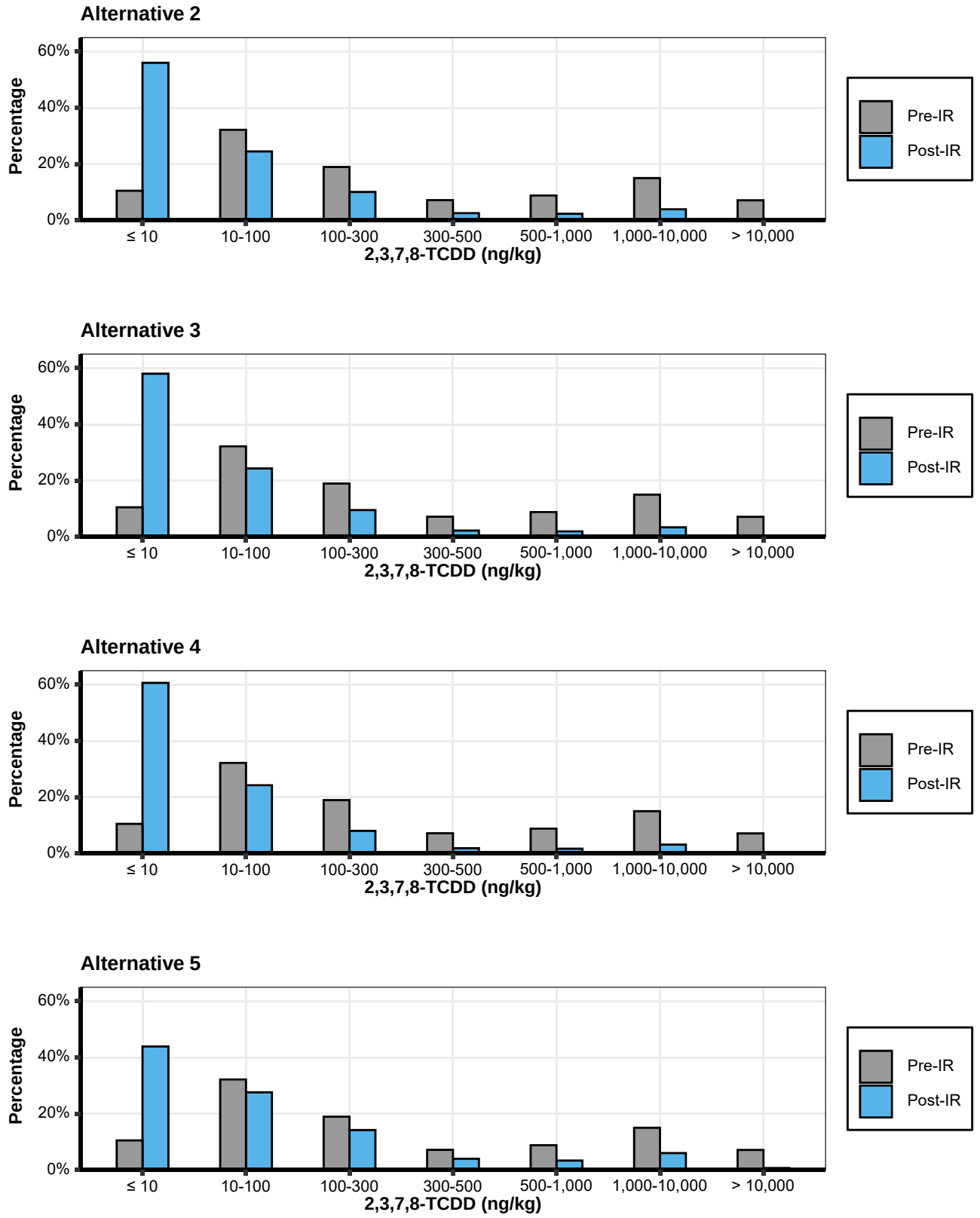
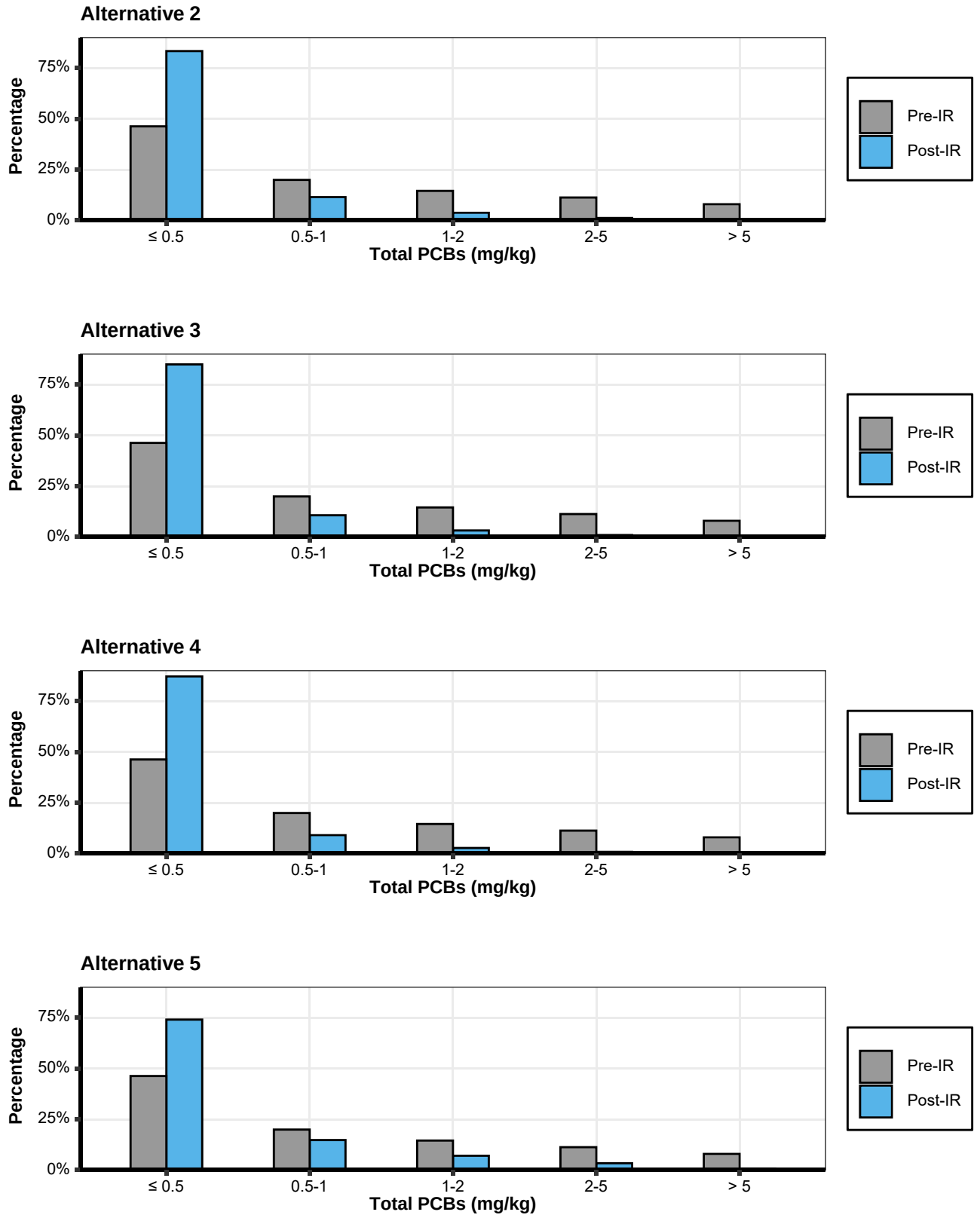


Note: The post-IR concentrations reflect substitution of replacement values of 10 ng/kg for 2,3,7,8-TCDD and 0 mg/kg for total PCBs within the active remedial footprints for each alternative. Post-IR concentrations higher than the RALs for each remedial alternative reflect targeting errors, as discussed in Appendix B.

Figure 8-3.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of 2,3,7,8-TCDD
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note: The post-IR concentrations reflect substitution of replacement values of 10 ng/kg for 2,3,7,8-TCDD and 0 mg/kg for total PCBs within the active remedial footprints for each alternative. Post-IR concentrations higher than the RALs for each remedial alternative reflect targeting errors, as discussed in Appendix B.

Figure 8-4.
Distribution of Pre- and Post-IR Surficial Sediment Concentrations of Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

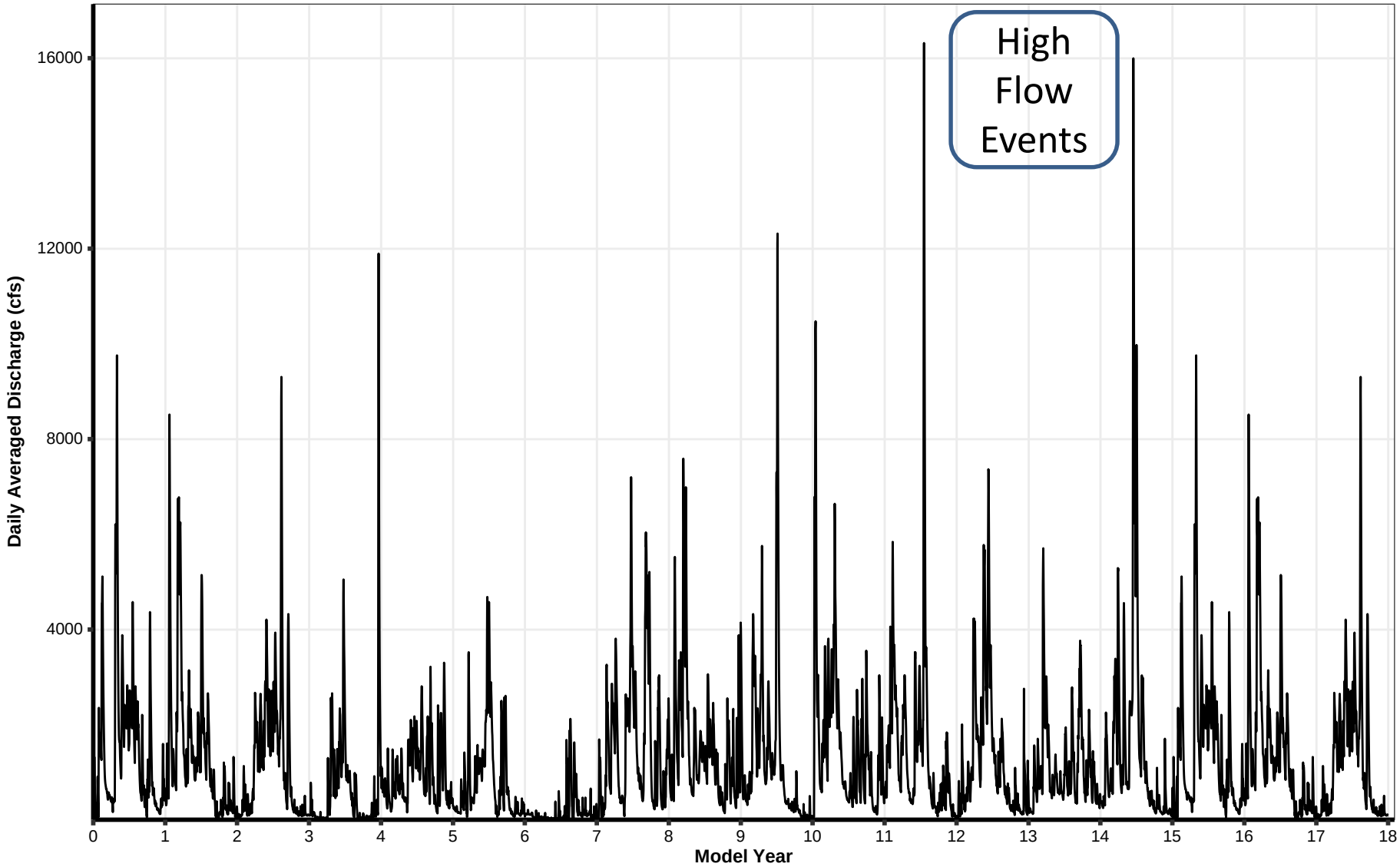
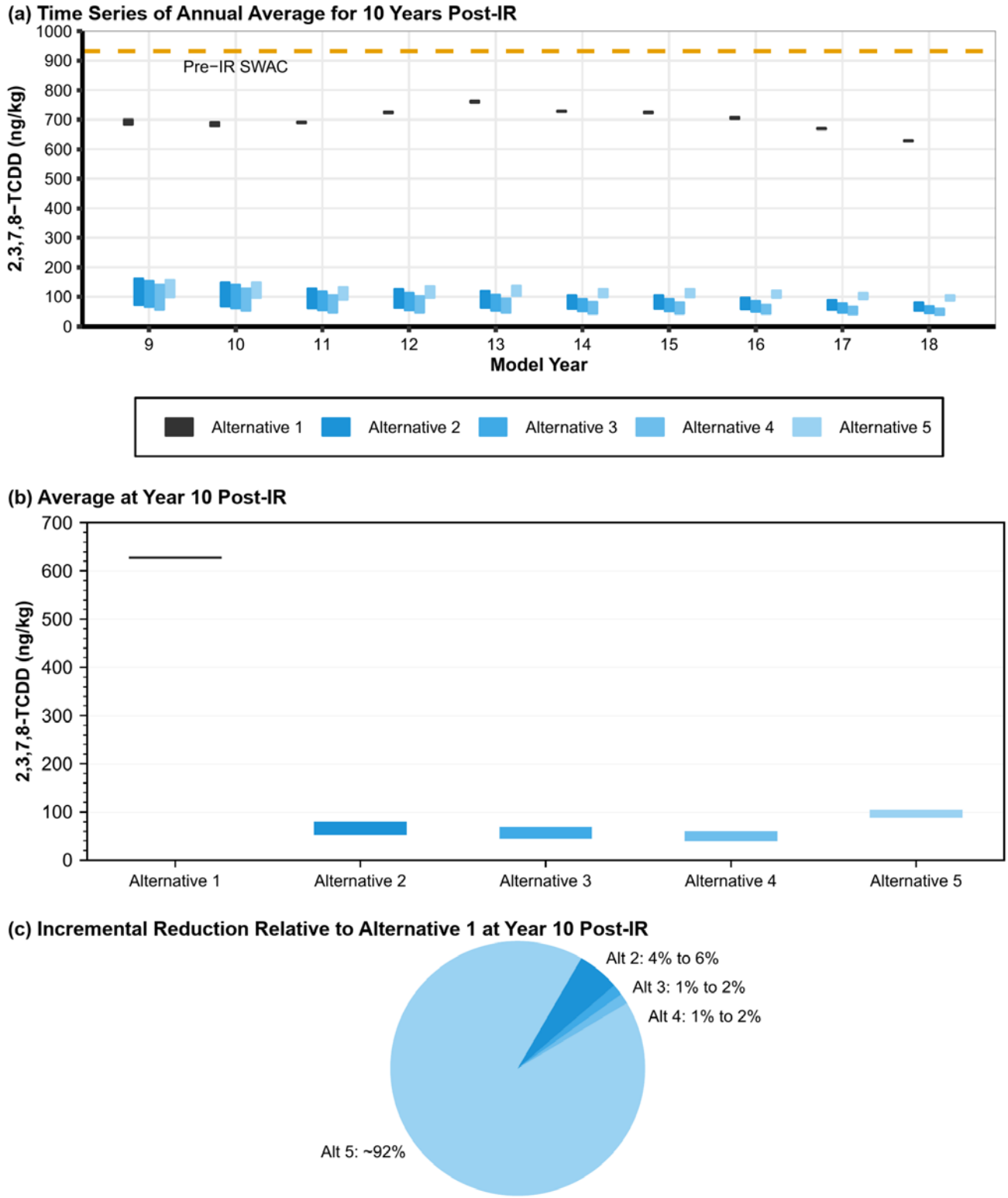
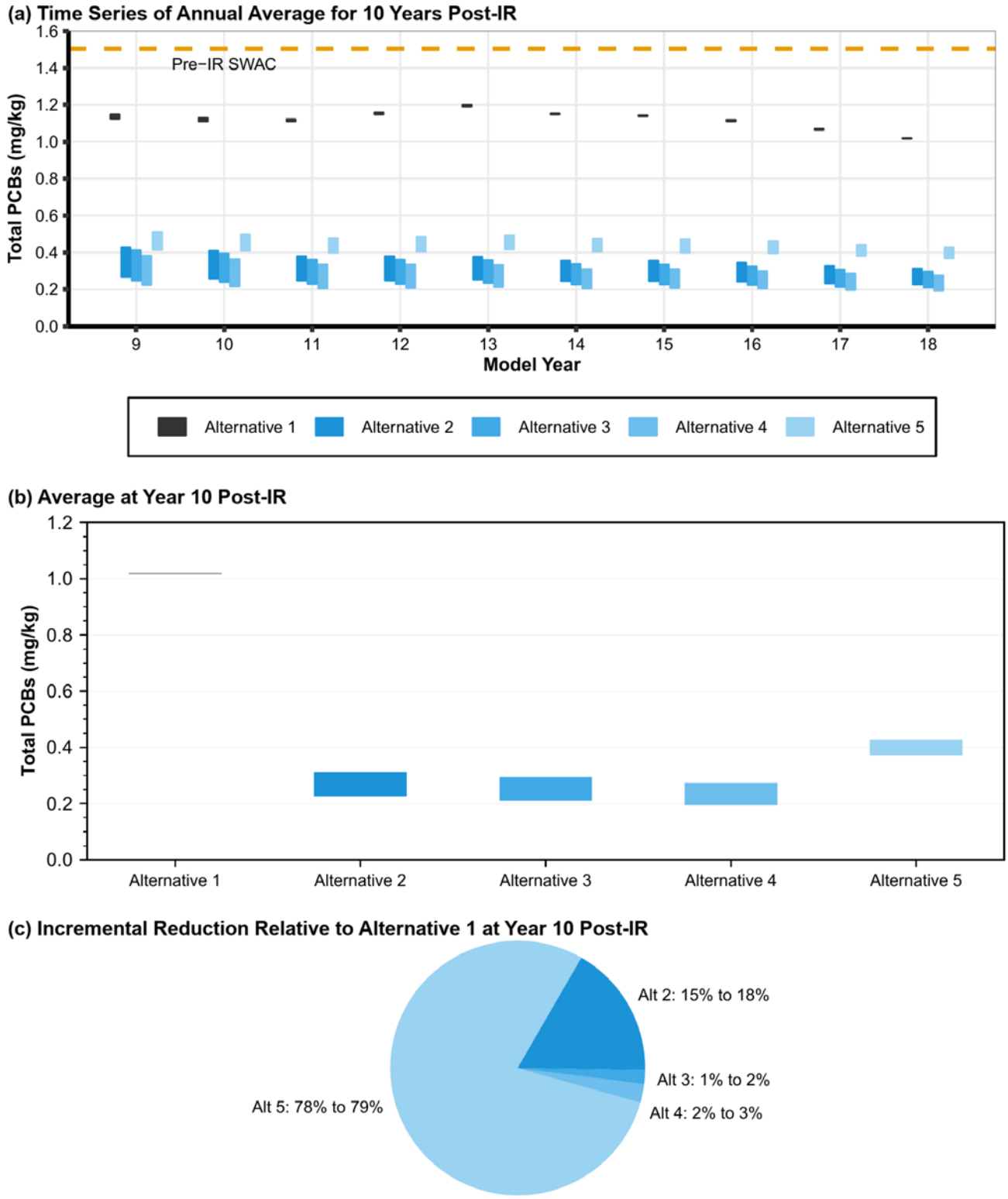


Figure 8-5.
Hydrograph Used for Model Projections
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



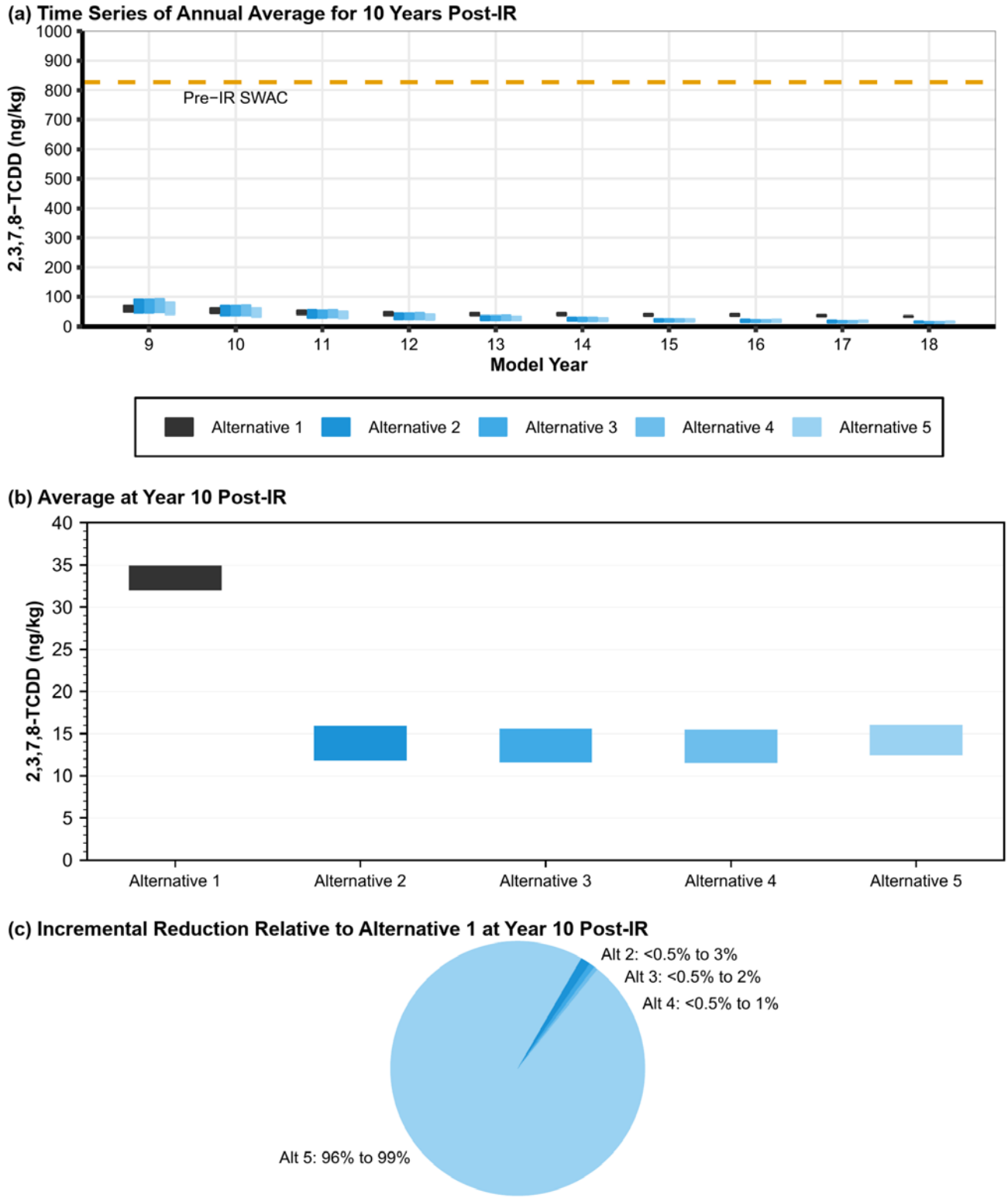
Note: Initial SWACs based on CS 37. Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-6.
Projected SWAC of 2,3,7,8-TCDD in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



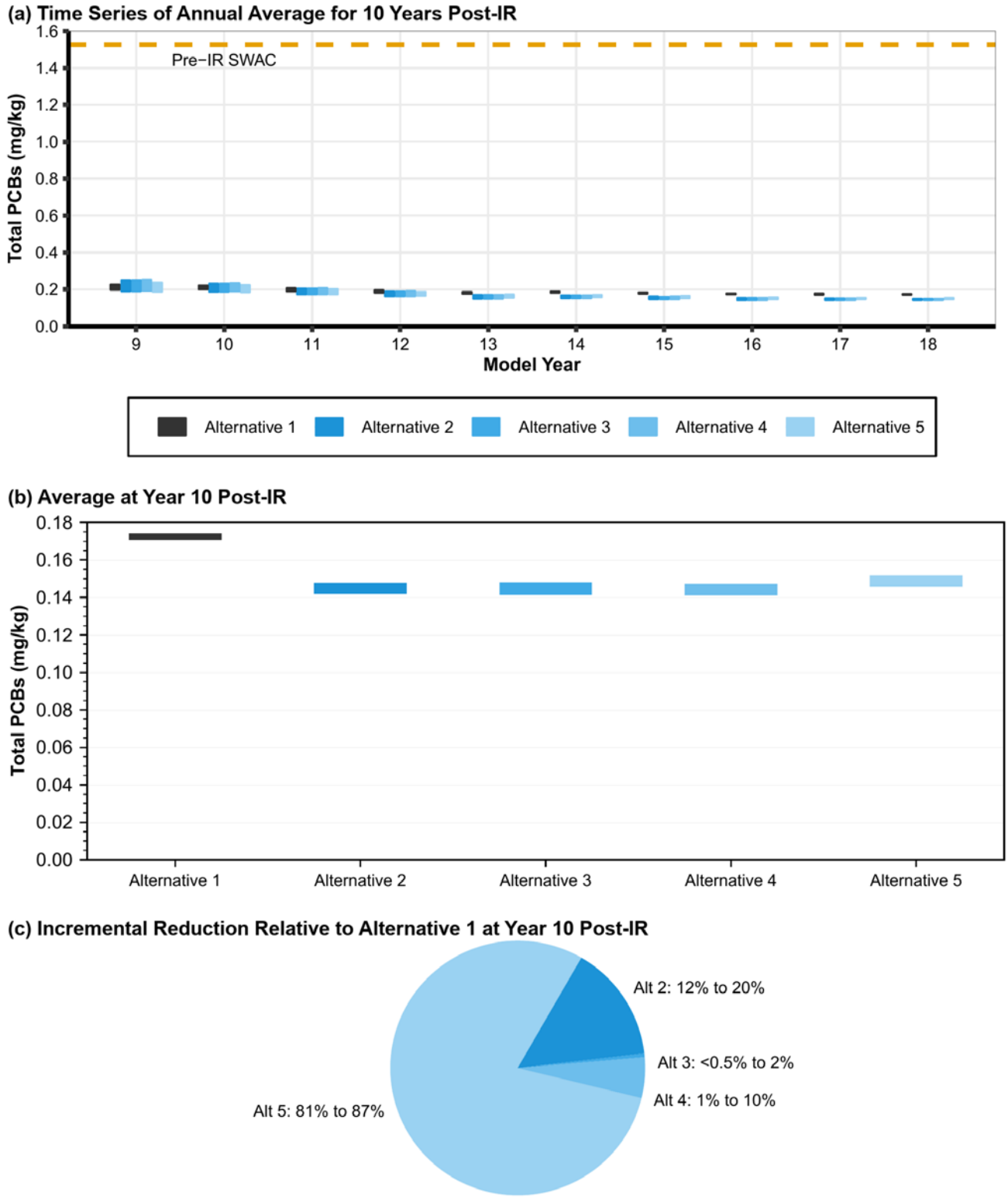
Note: Initial SWACs based on CS 37. Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-7.
Projected SWAC of Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



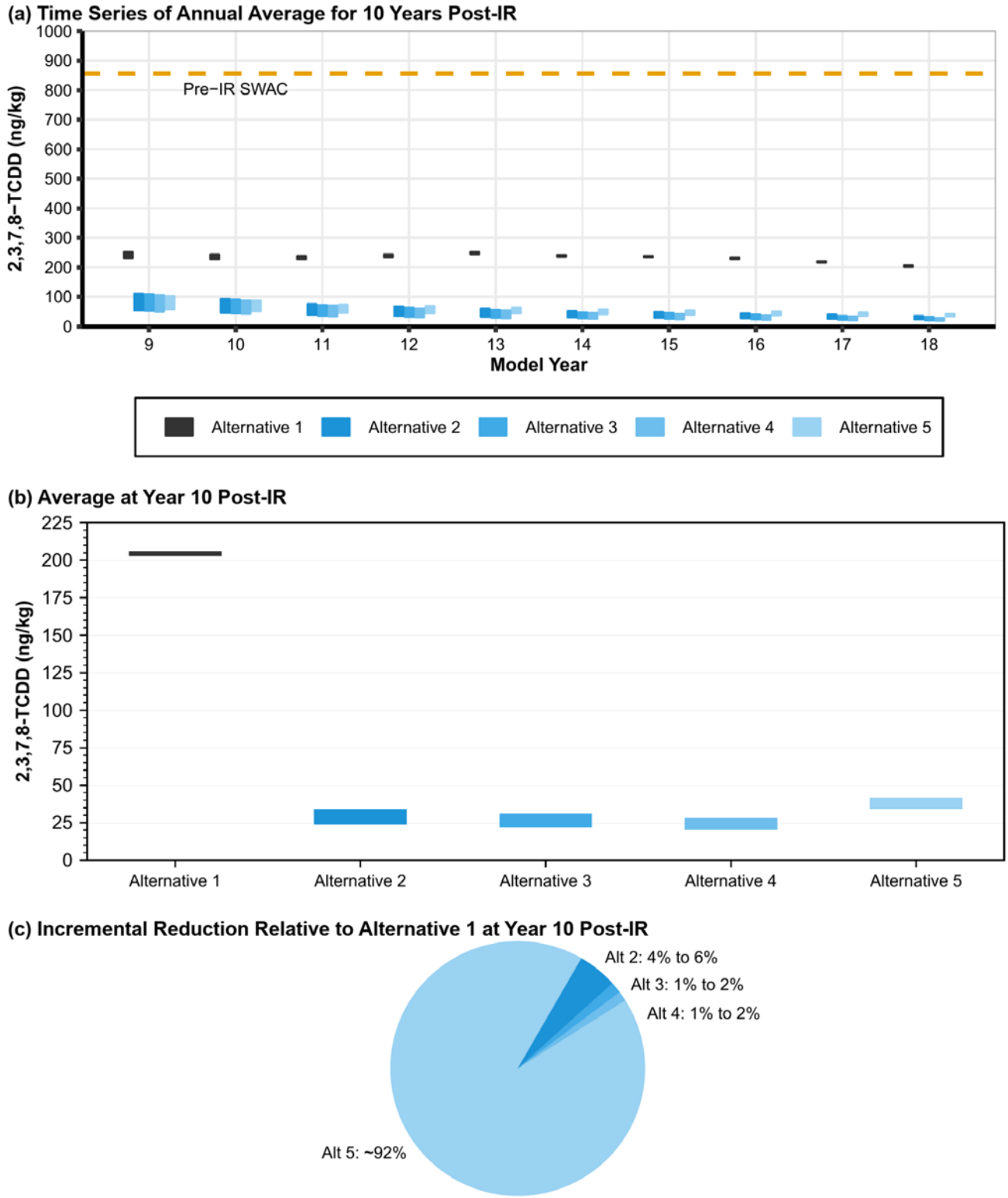
Note: Initial SWACs based on CS 37. Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-8.
Projected SWAC of 2,3,7,8-TCDD in RM 0 to RM 8.3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



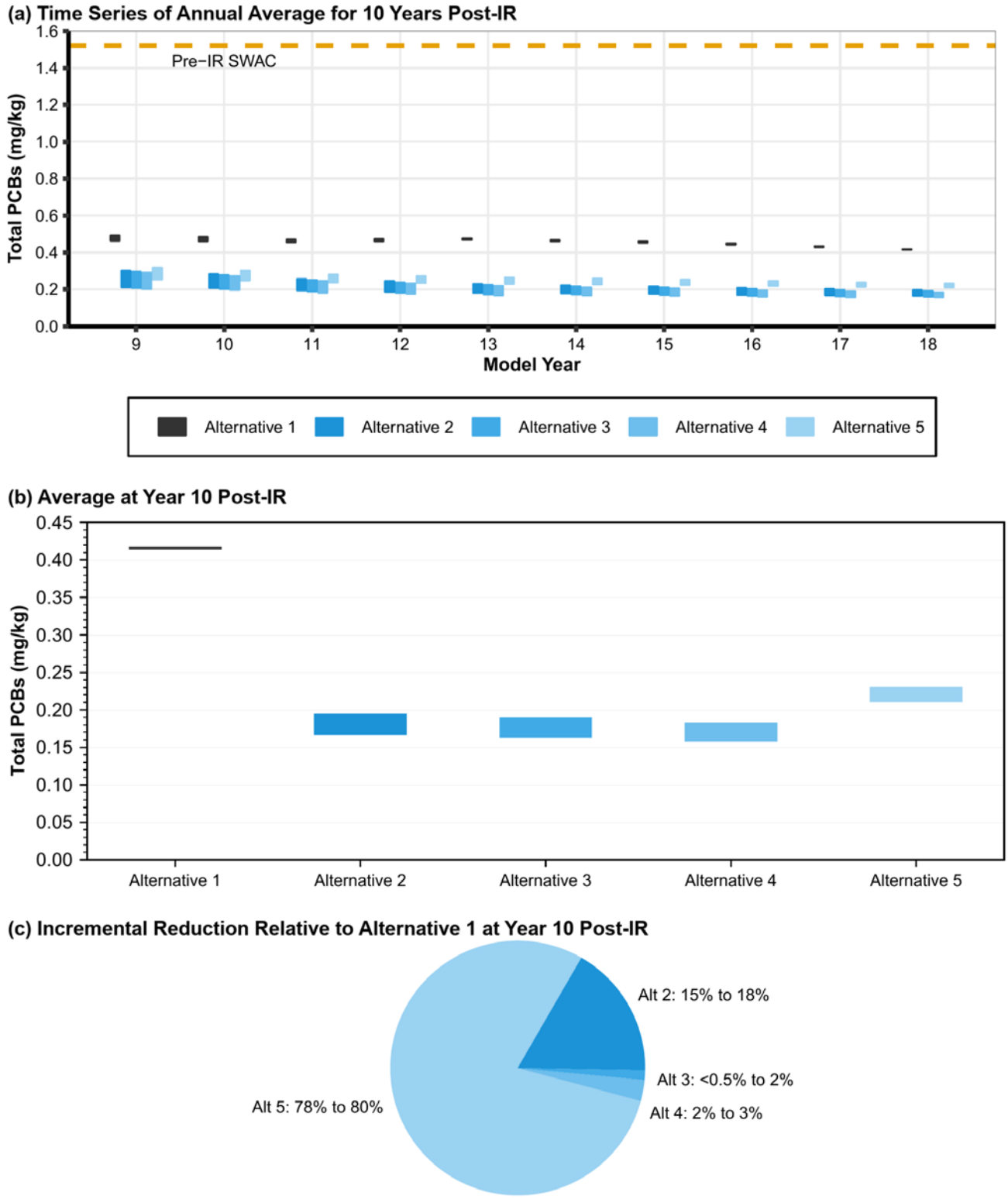
Note: Initial SWACs based on CS 37. Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-9.
Projected SWAC of Total PCBs in RM 0 to RM 8.3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



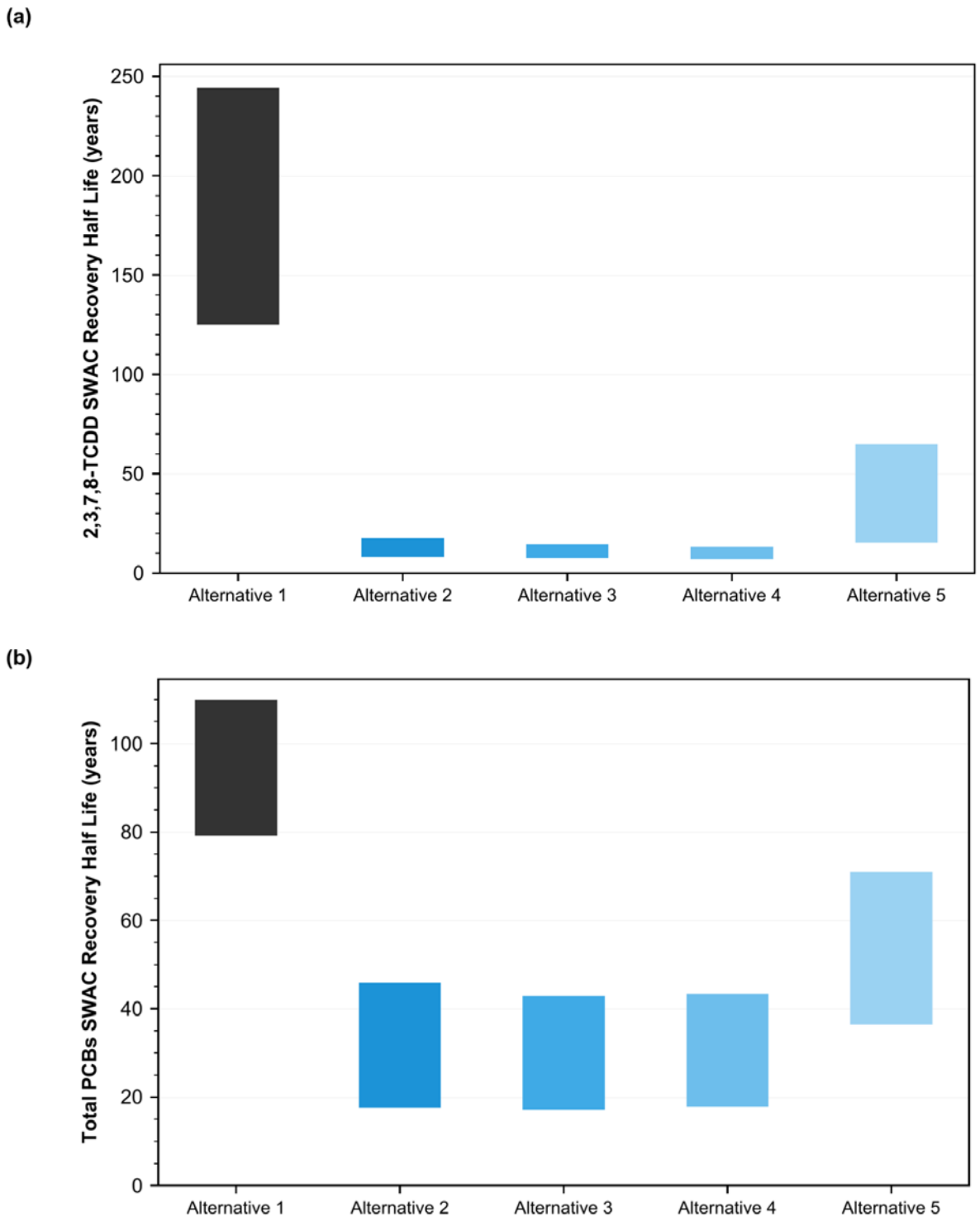
Note: Initial SWACs based on CS 37. Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-10.
Projected SWAC of 2,3,7,8-TCDD in RM 0 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



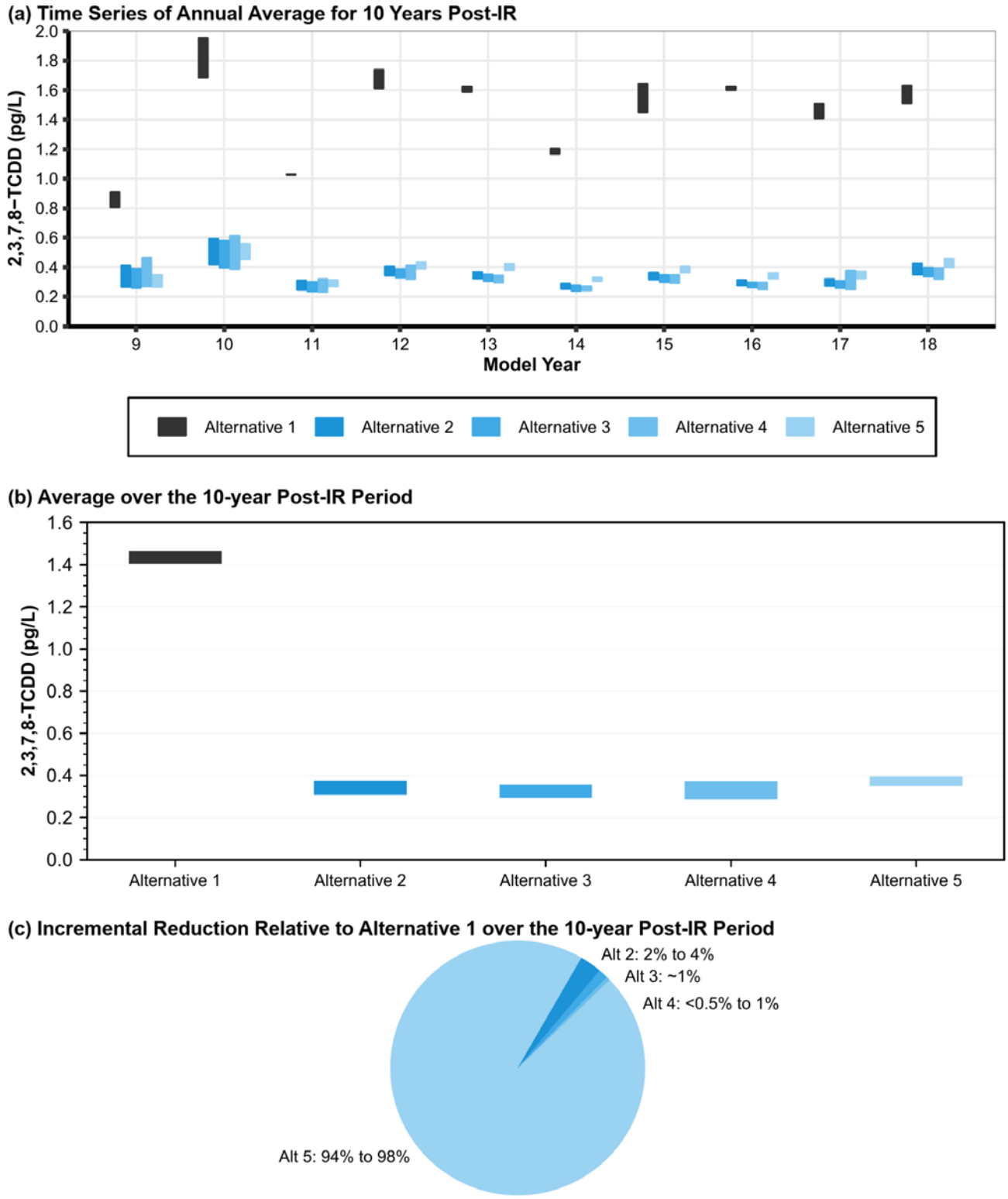
Note: Initial SWACs based on CS 37. Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-11.
Projected SWAC of Total PCBs in RM 0 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



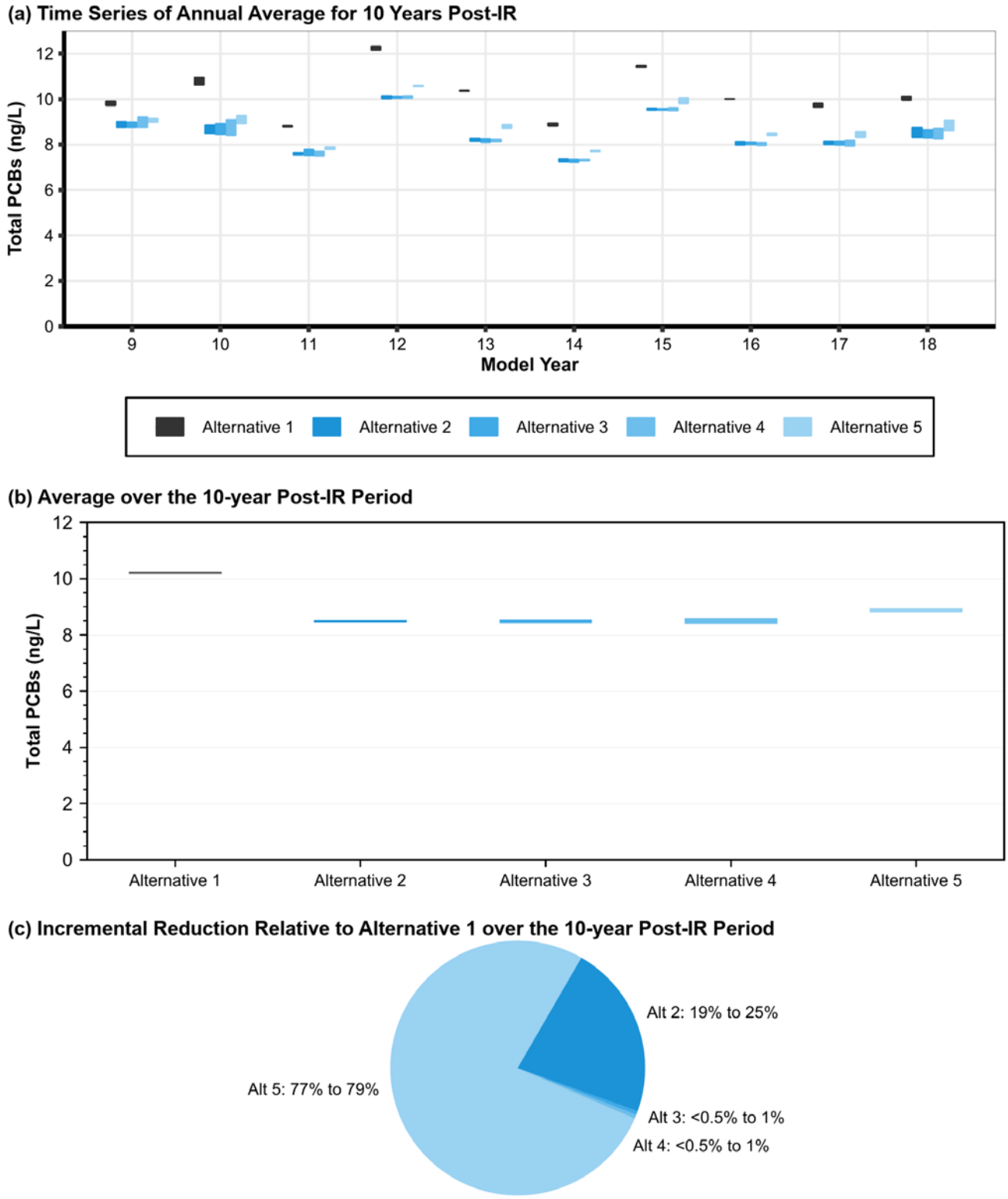
Note: Bars on panels (a) and (b) represent range of estimated recovery half-lives from runs characterizing sensitivity to selected model input parameters.

Figure 8-12.
Estimated SWAC Recovery Half-Life in RM 8.3 to 15 Over the Projected 10-Year Post-IR Period for (a) 2,3,7,8-TCDD and (b) Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



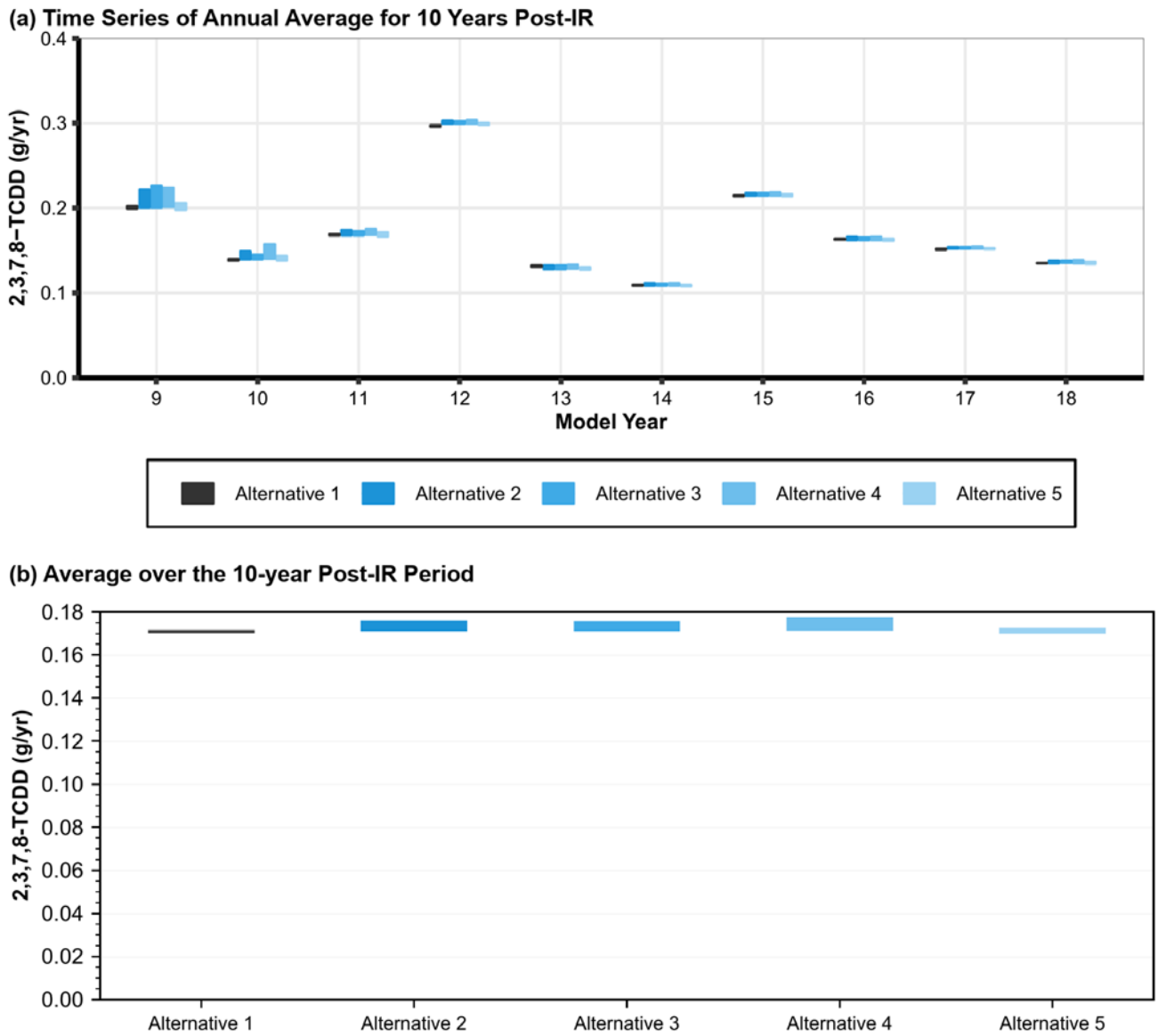
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-13.
Projected Water Column Concentration of 2,3,7,8-TCDD in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



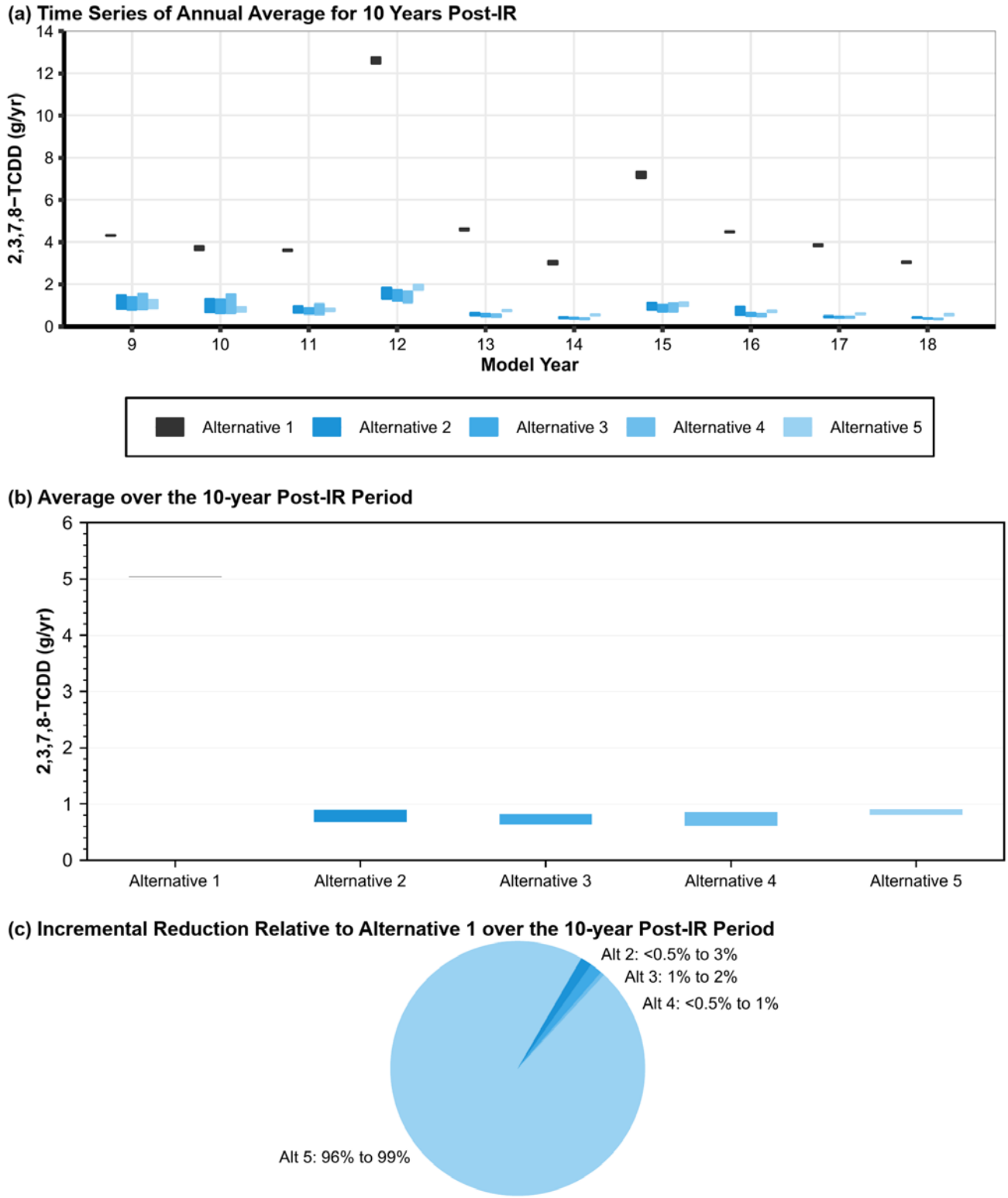
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-14.
Projected Water Column Concentration of Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



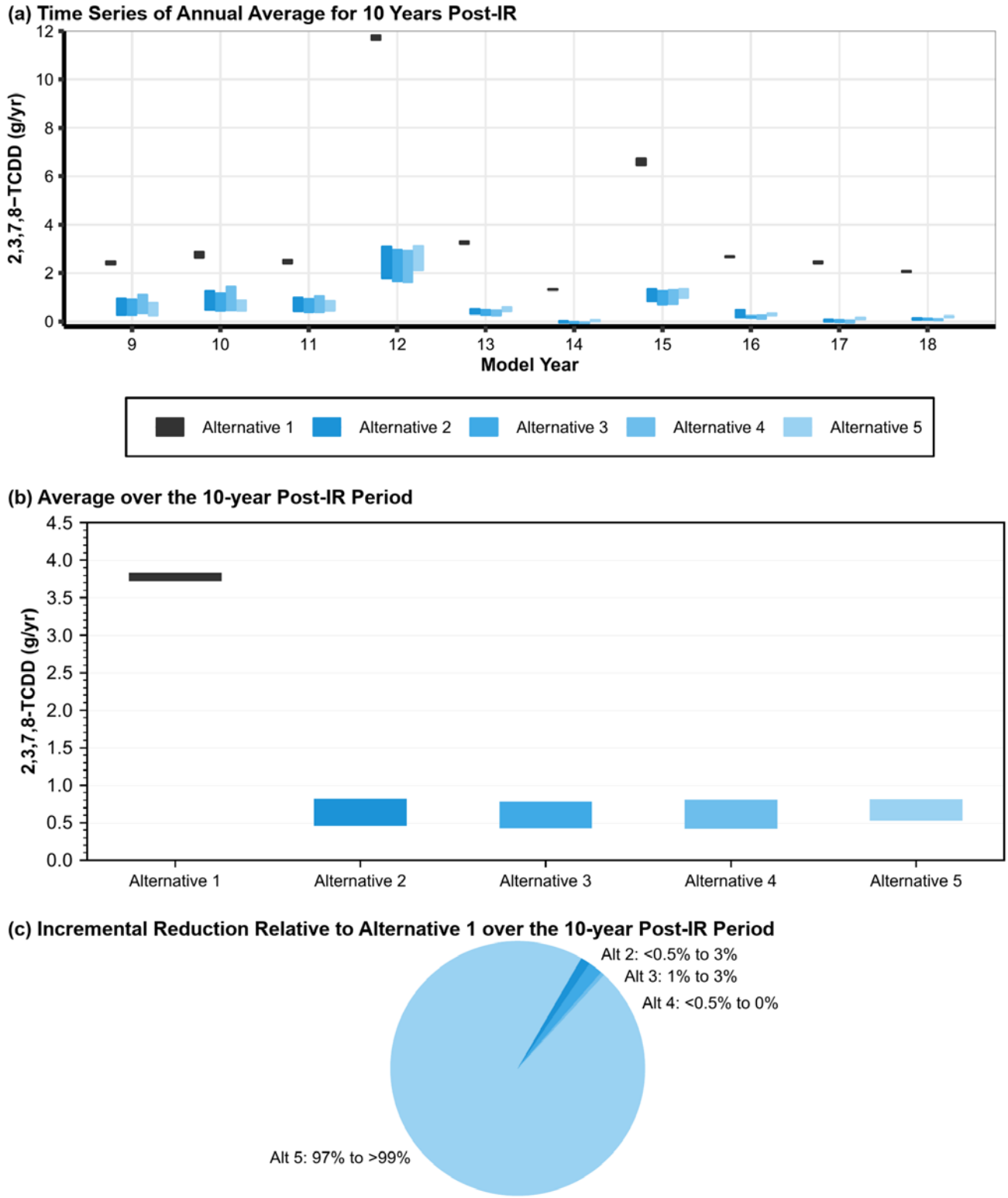
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. The incremental reduction of each active alternative relative to Alternative 1 is not shown here because the alternatives do not have a material impact on the RM 15 load.

Figure 8-15.
Projected Water Column Downstream Load of 2,3,7,8-TCDD at RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



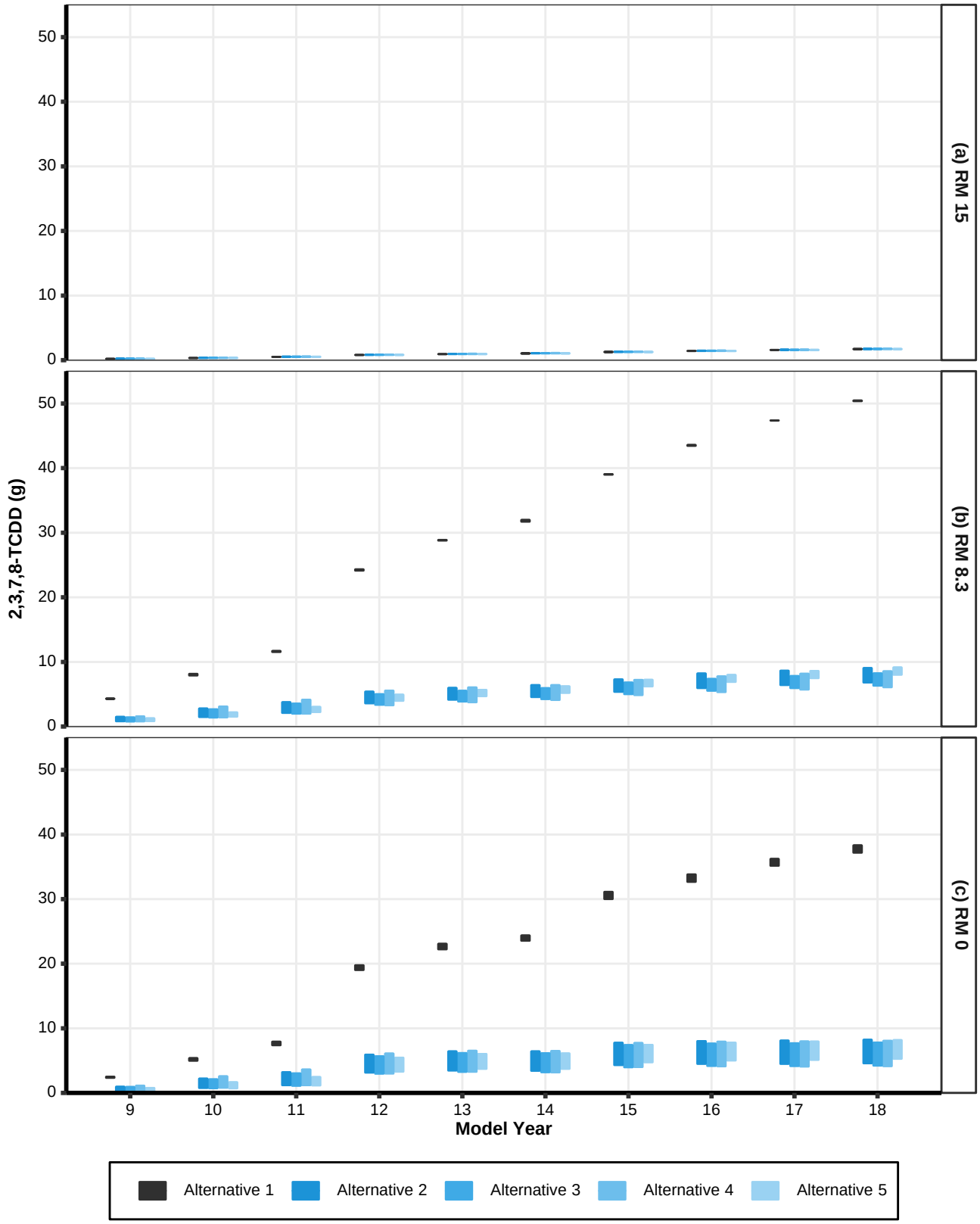
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-16.
Projected Water Column Downstream Load of 2,3,7,8-TCDD at RM 8.3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



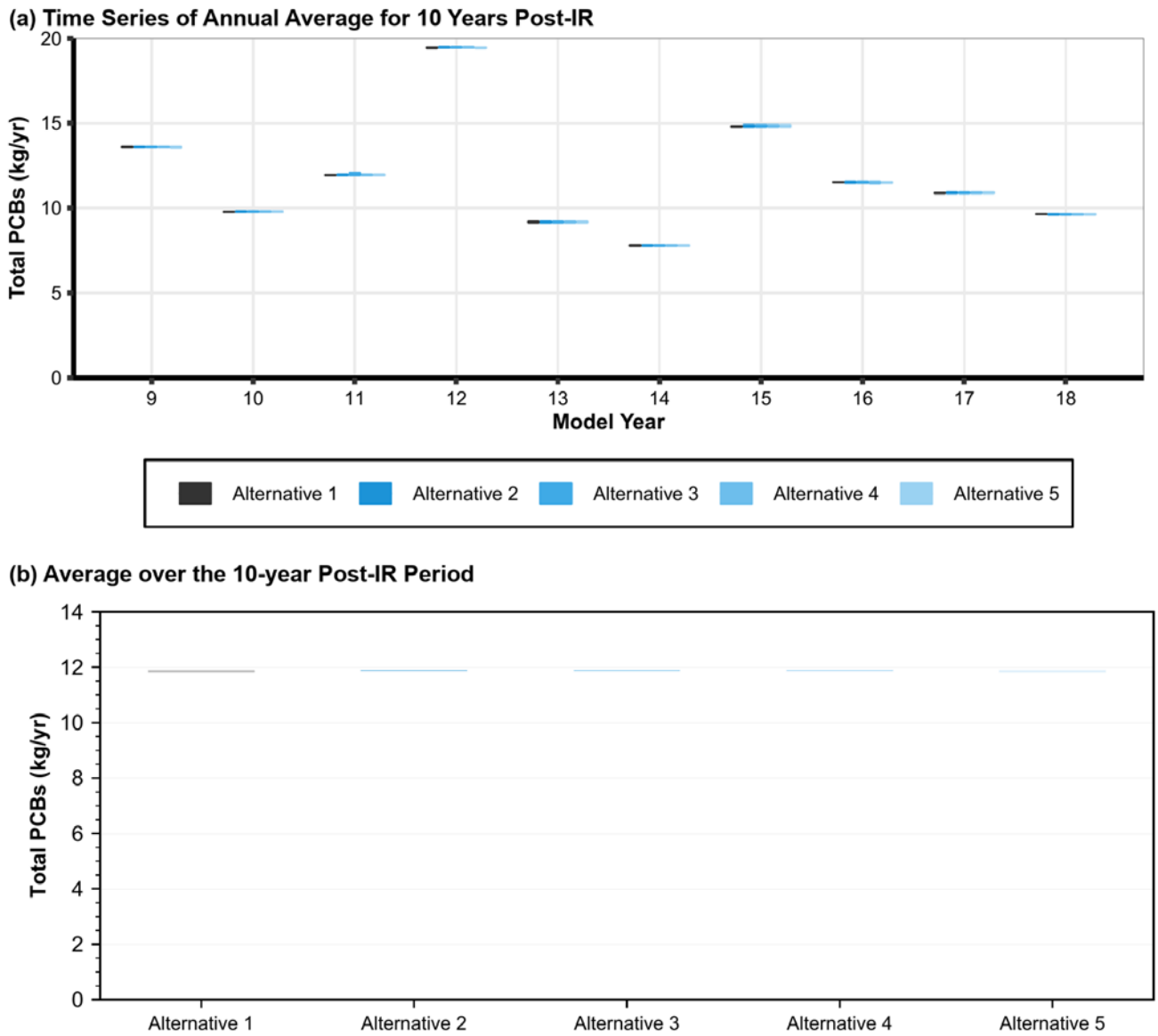
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-17.
Projected Water Column Downstream Load of 2,3,7,8-TCDD at RM 0
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



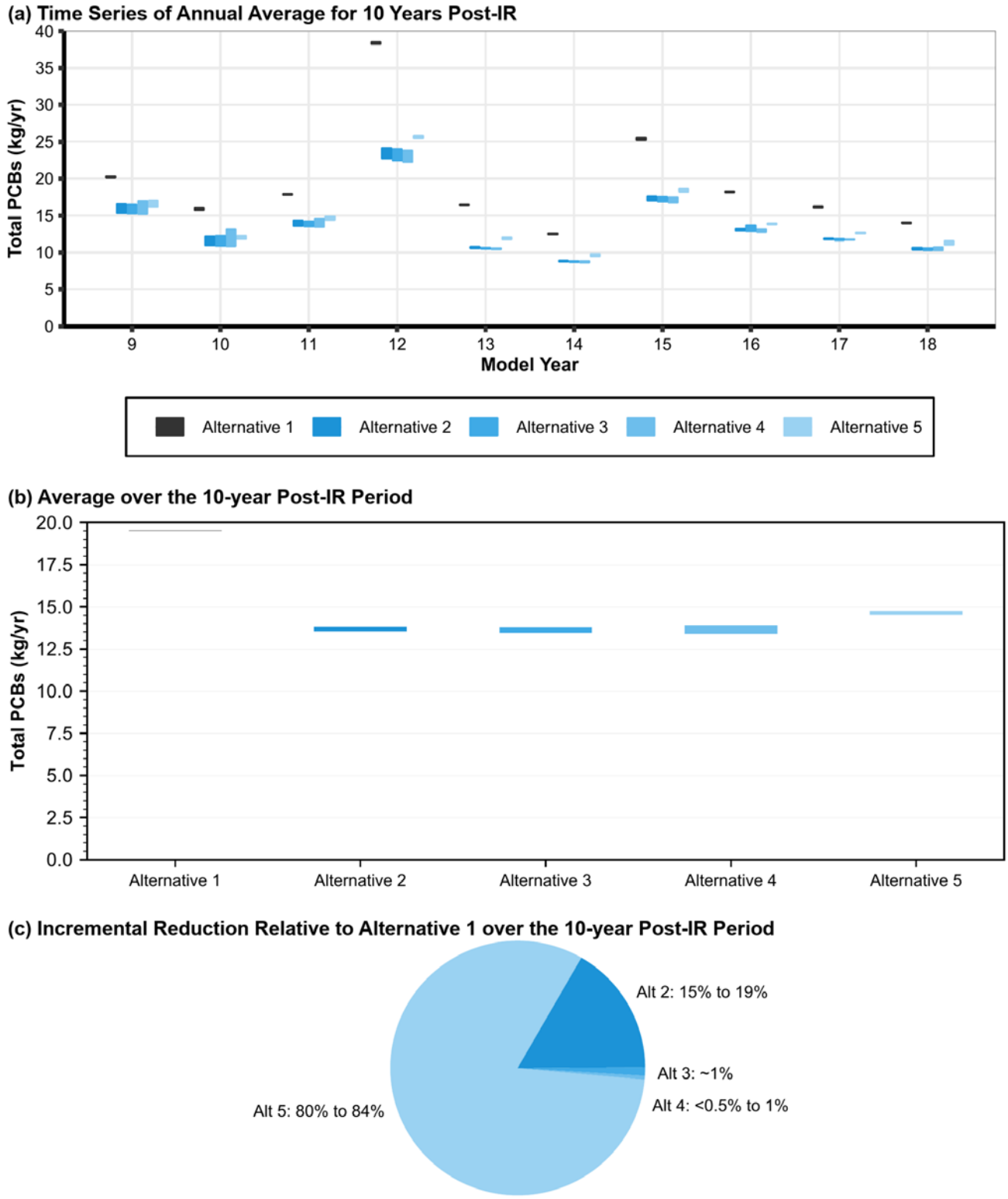
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 8-18.
Projected Cumulative Water Column Downstream Load of 2,3,7,8-TCDD at (a) RM 15, (b) RM 8.3, (c) RM 0, Time Series for 10 Years Post-IR
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



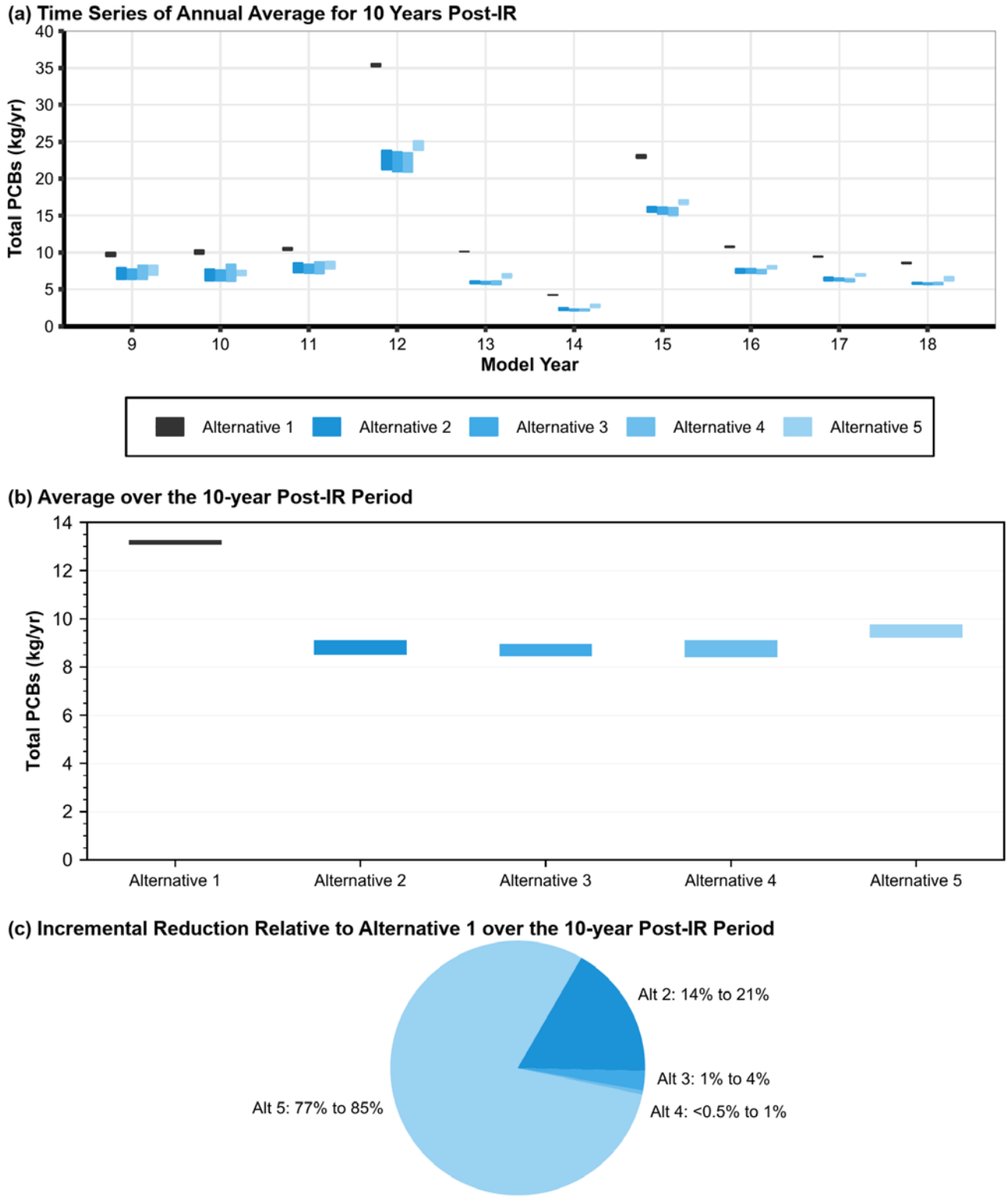
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. The incremental reduction of each active alternative relative to Alternative 1 is not shown here because the alternatives do not have a material impact on the RM 15 load.

Figure 8-19.
Projected Water Column Downstream Load of Total PCBs at RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



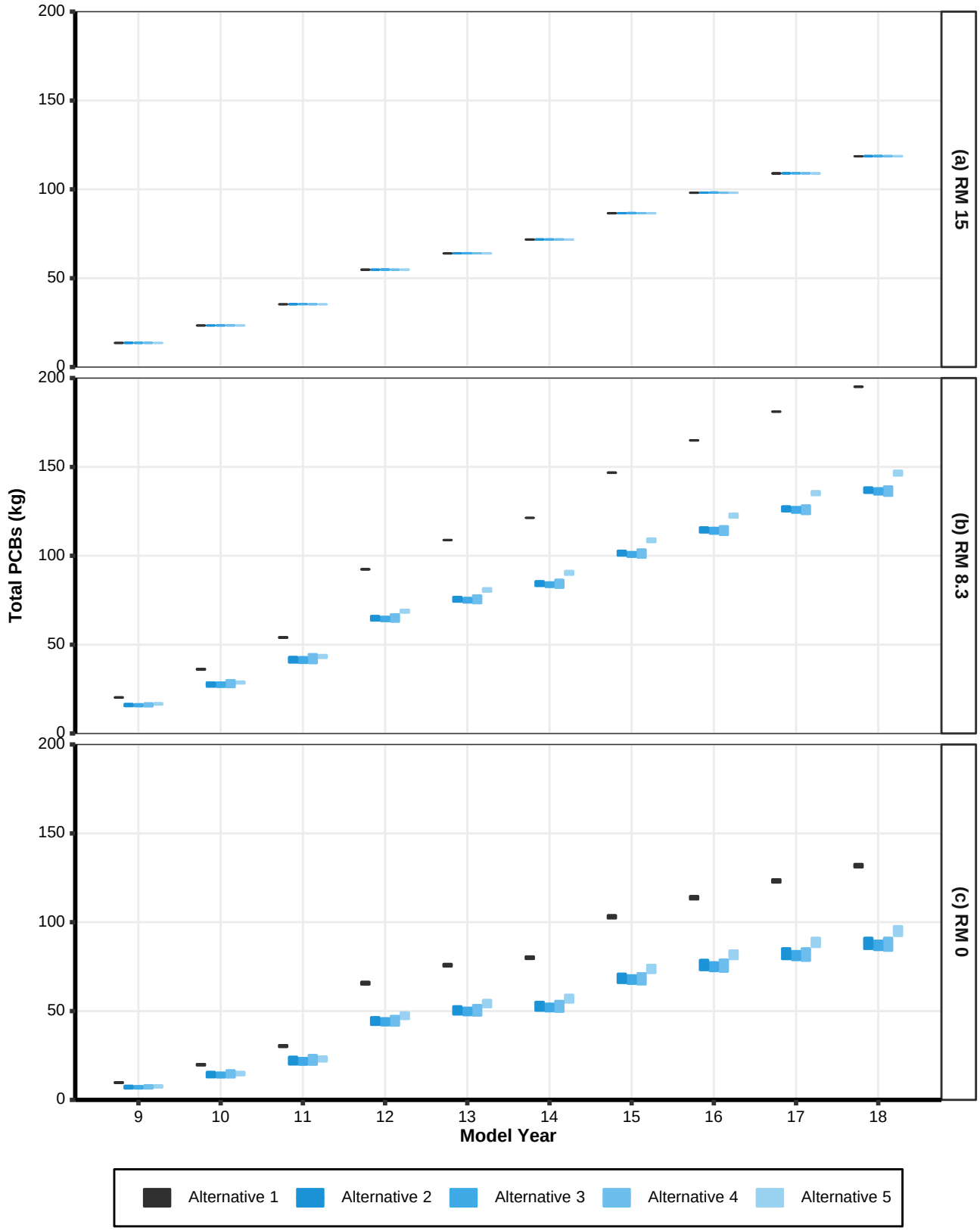
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-20.
Projected Water Column Downstream Load of Total PCBs at RM 8.3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



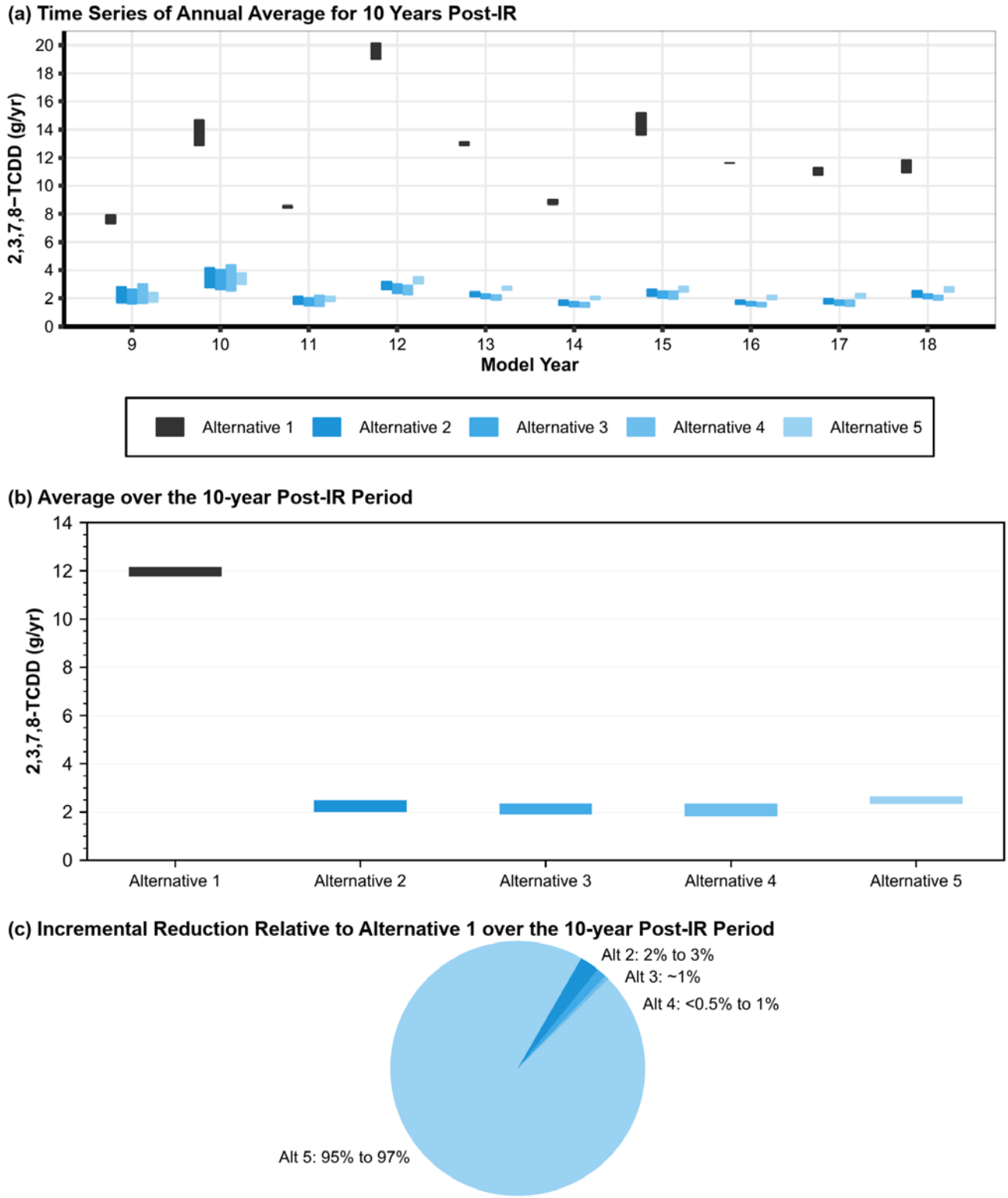
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-21.
Projected Water Column Downstream Load of Total PCBs at RM 0
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



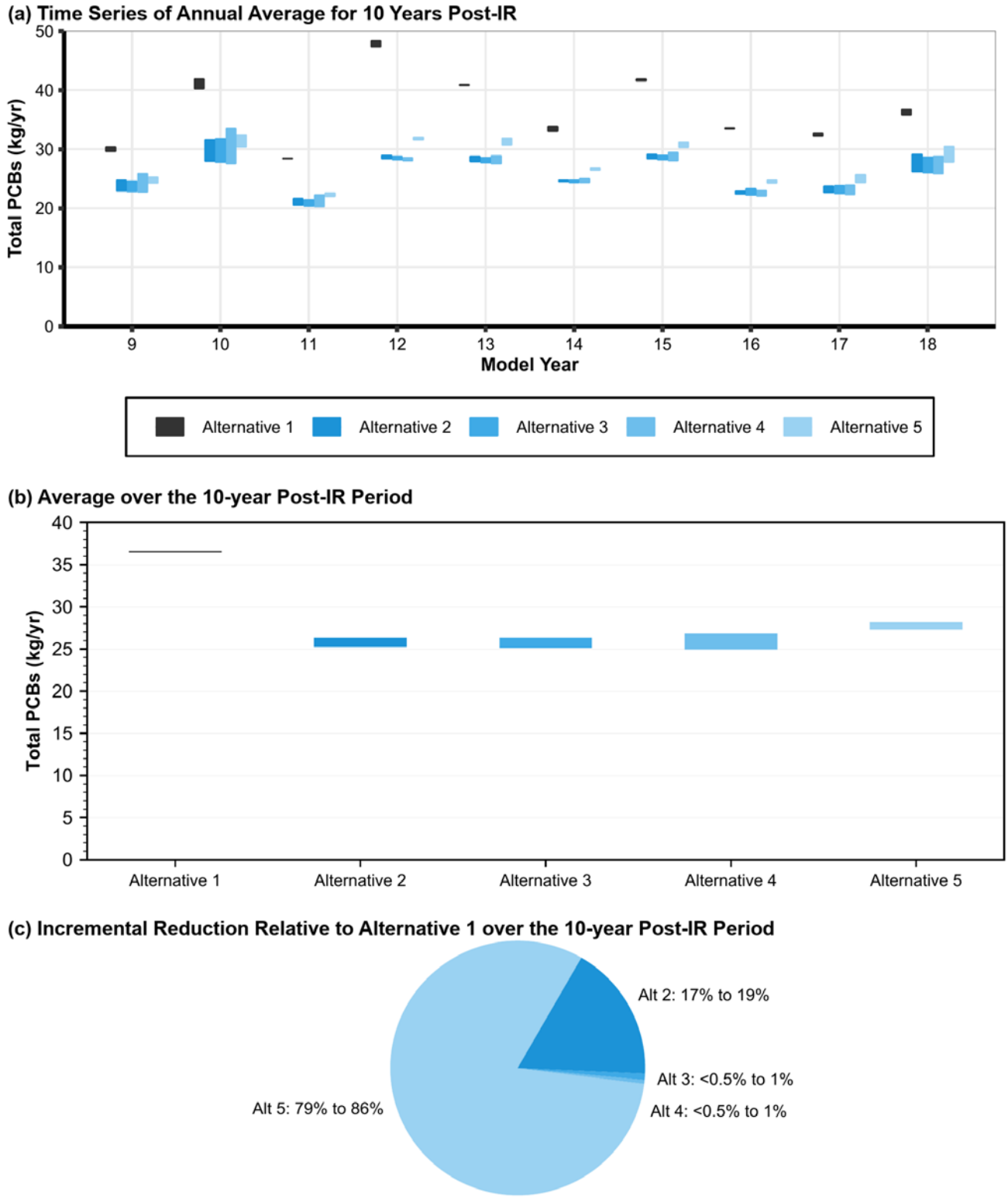
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 8-22.
Projected Cumulative Water Column Downstream Load of Total PCBs at (a) RM 15, (b) RM 8.3, (c) RM 0, Time Series for 10 Years Post-IR
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



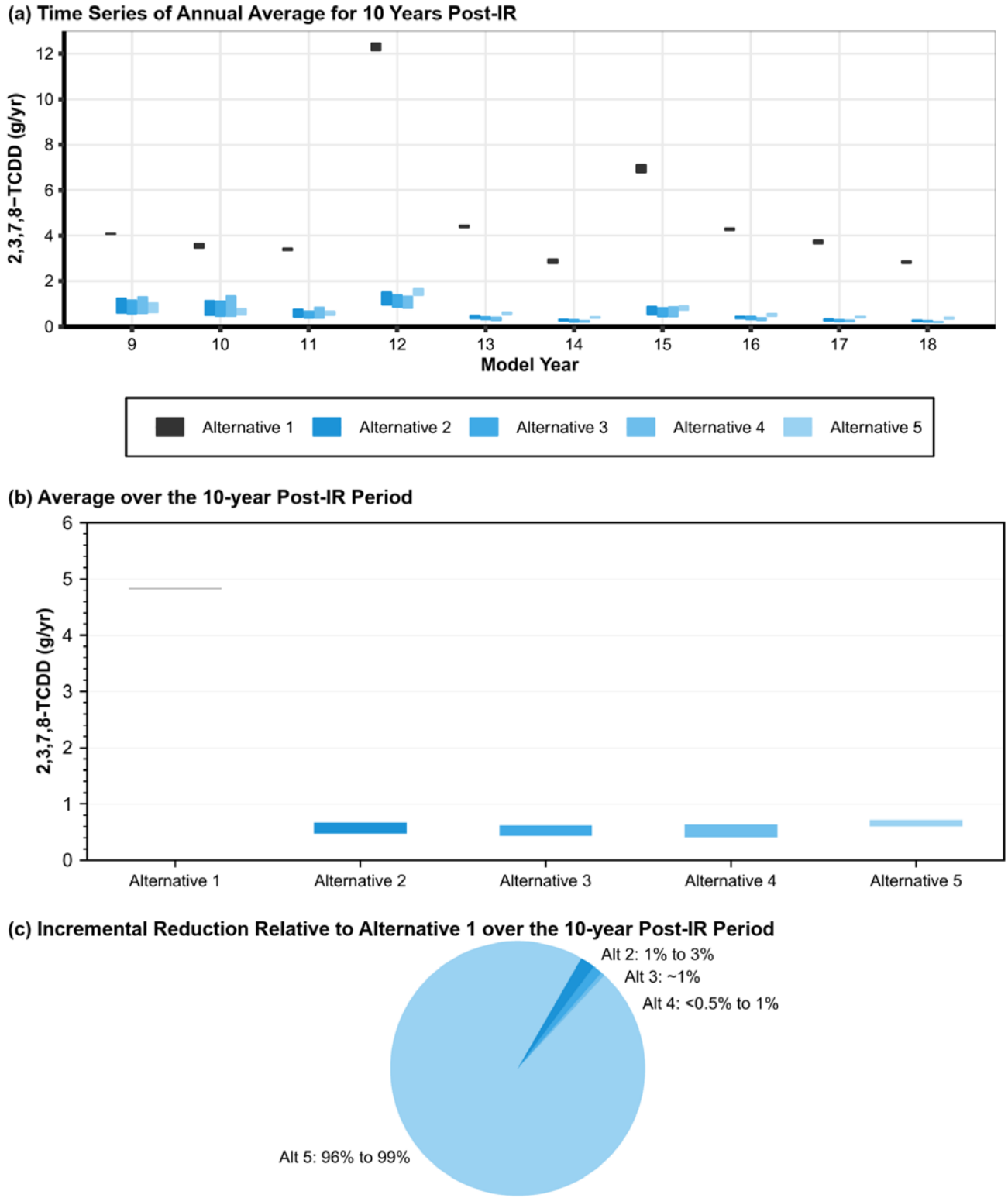
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-23.
Projected Gross Erosional Flux of 2,3,7,8-TCDD in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



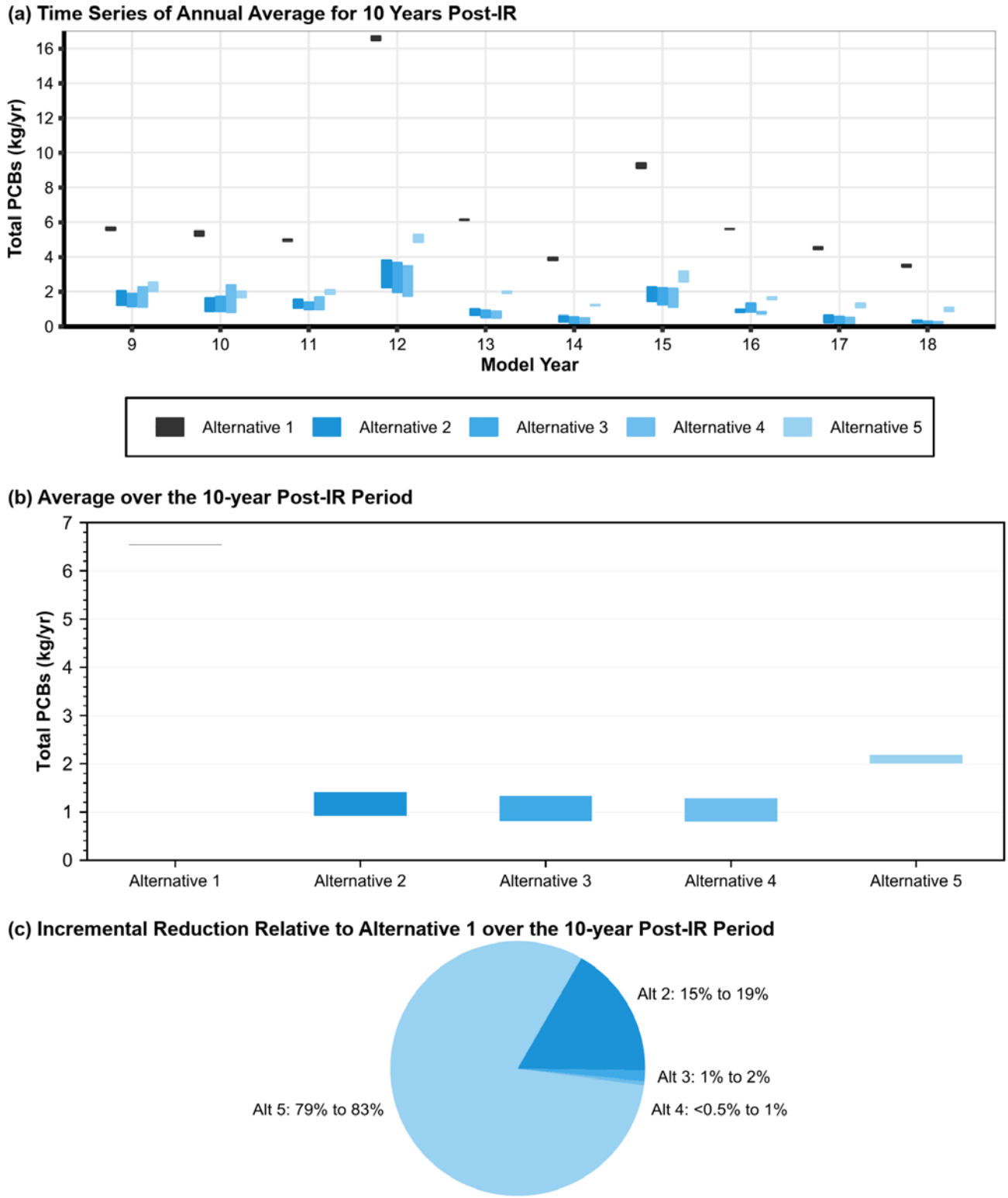
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-24.
Projected Gross Erosional Flux of Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



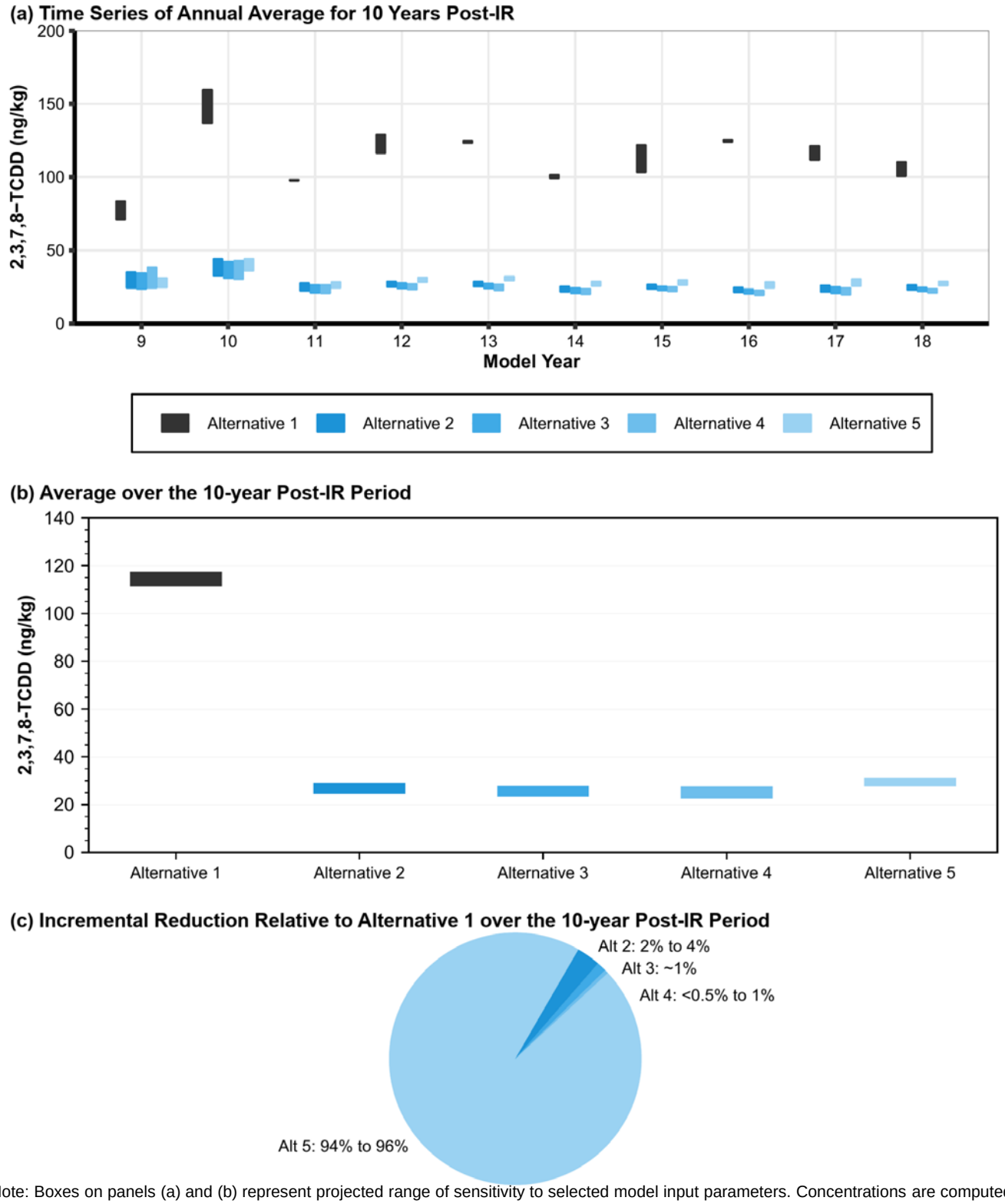
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-25.
Projected Net Erosional Flux of 2,3,7,8-TCDD in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



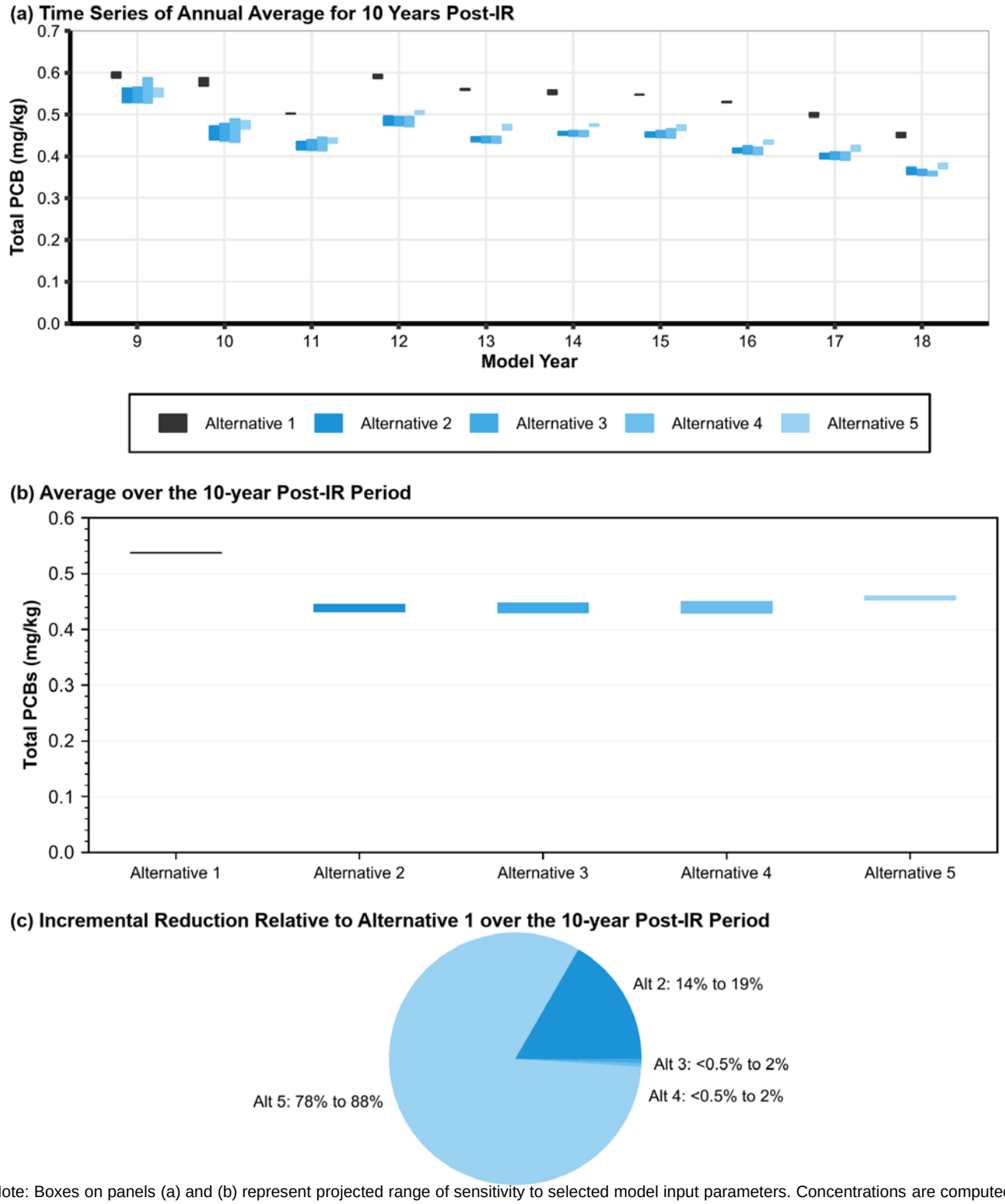
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-26.
Projected Net Erosional Flux of Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



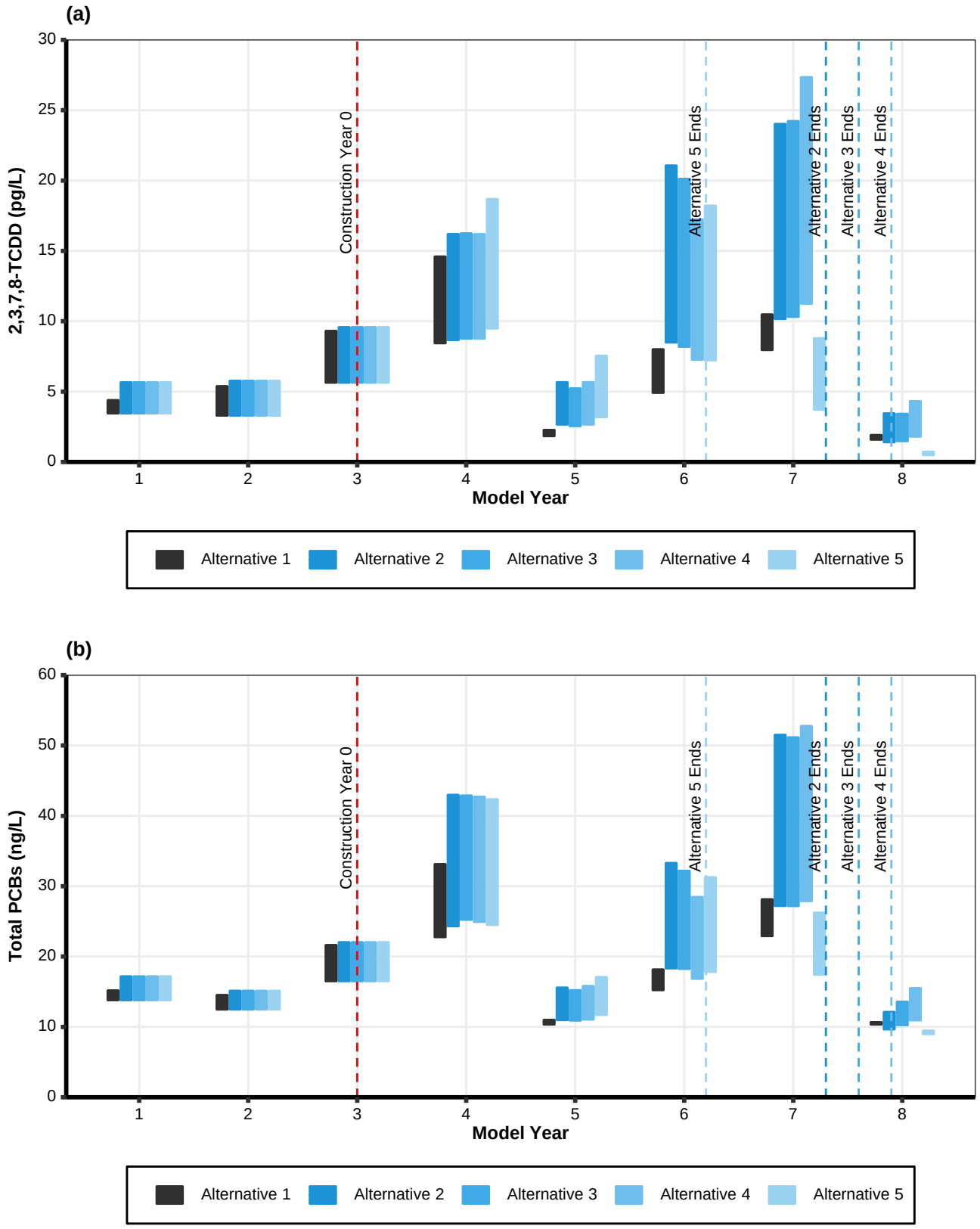
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Concentrations are computed as the ratio of total chemical deposition flux to total cohesive sediment deposition flux over one year periods in panel (a) and over the full 10-year post-IR period in panel (b). Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-27.
Projected Concentration on Depositing Fine Sediment of 2,3,7,8-TCDD in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



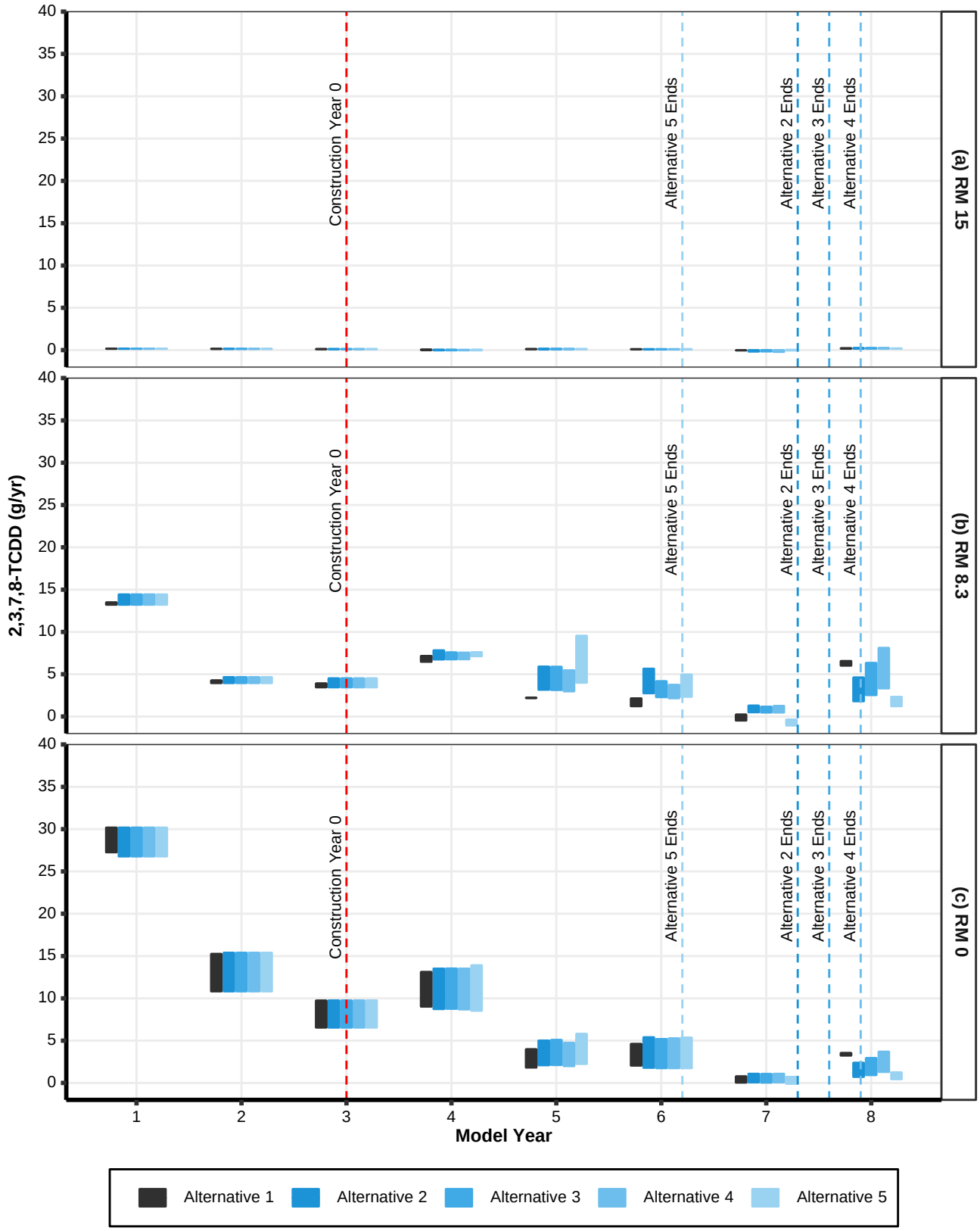
Note: Boxes on panels (a) and (b) represent projected range of sensitivity to selected model input parameters. Concentrations are computed as the ratio of total chemical deposition flux to total cohesive sediment deposition flux over one year periods in panel (a) and over the full 10-year post-IR period in panel (b). Panel (c) shows the incremental projected reduction of each active alternative, moving from the smallest (Alternative 5) to the largest (Alternative 4). The incremental reductions are expressed as fractions of the overall reduction between Alternative 1 and Alternative 4, and shown as ranges for each alternative. For visualization, the slices of the pie chart are proportional to the mid-point of the alternative's projected reductions (if the mid-point of the range is smaller than 0.5%, then a value of 0.5% was used).

Figure 8-28.
Projected Concentration on Depositing Fine Sediment of Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



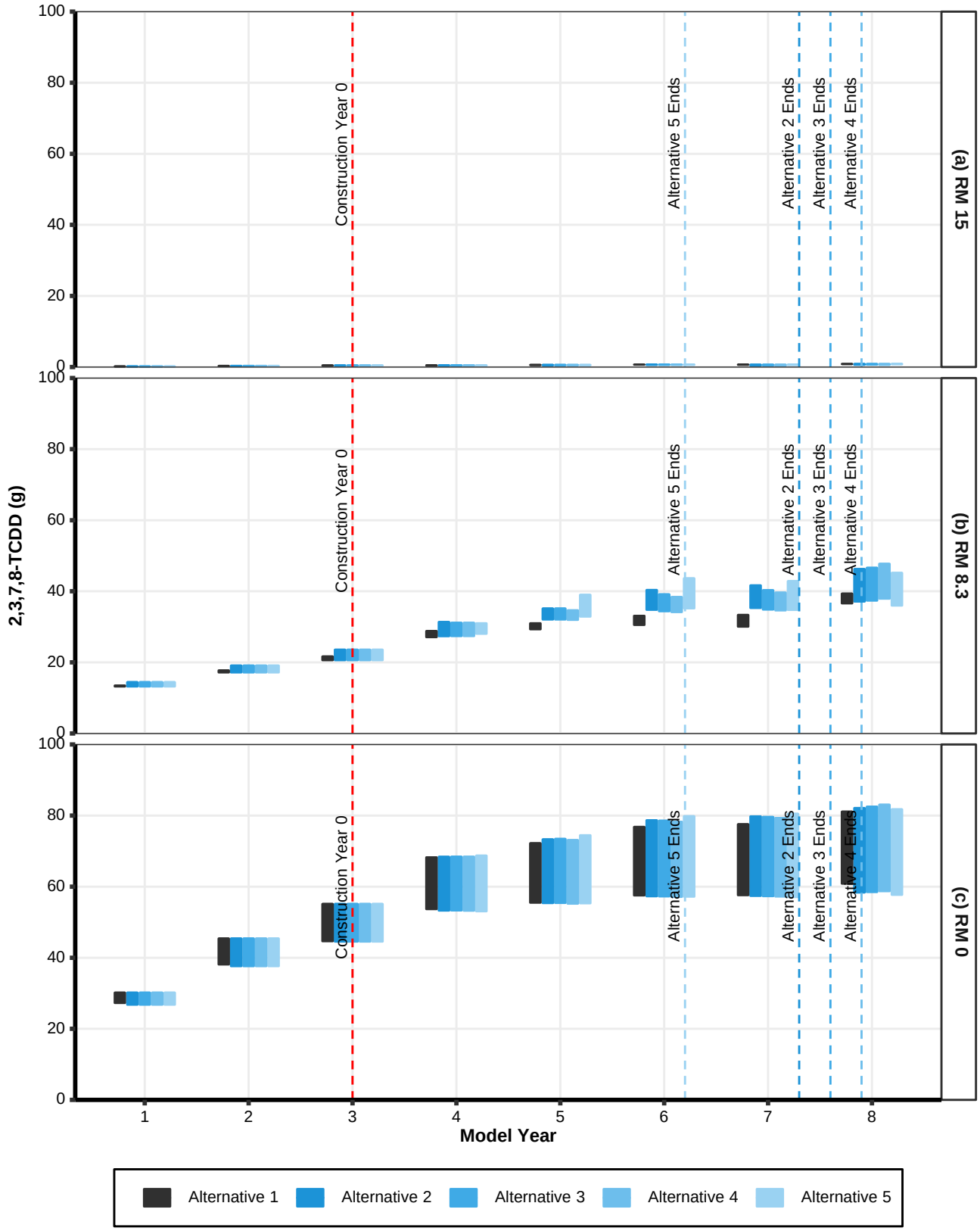
Note: Boxes represent projected range of sensitivity to selected model input parameters.

Figure 8-29.
Projected Annual Average Water Column Concentrations of (a) 2,3,7,8-TCDD and (b) Total PCBs in RM 8.3 to RM 15 during Pre-IR Completion Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



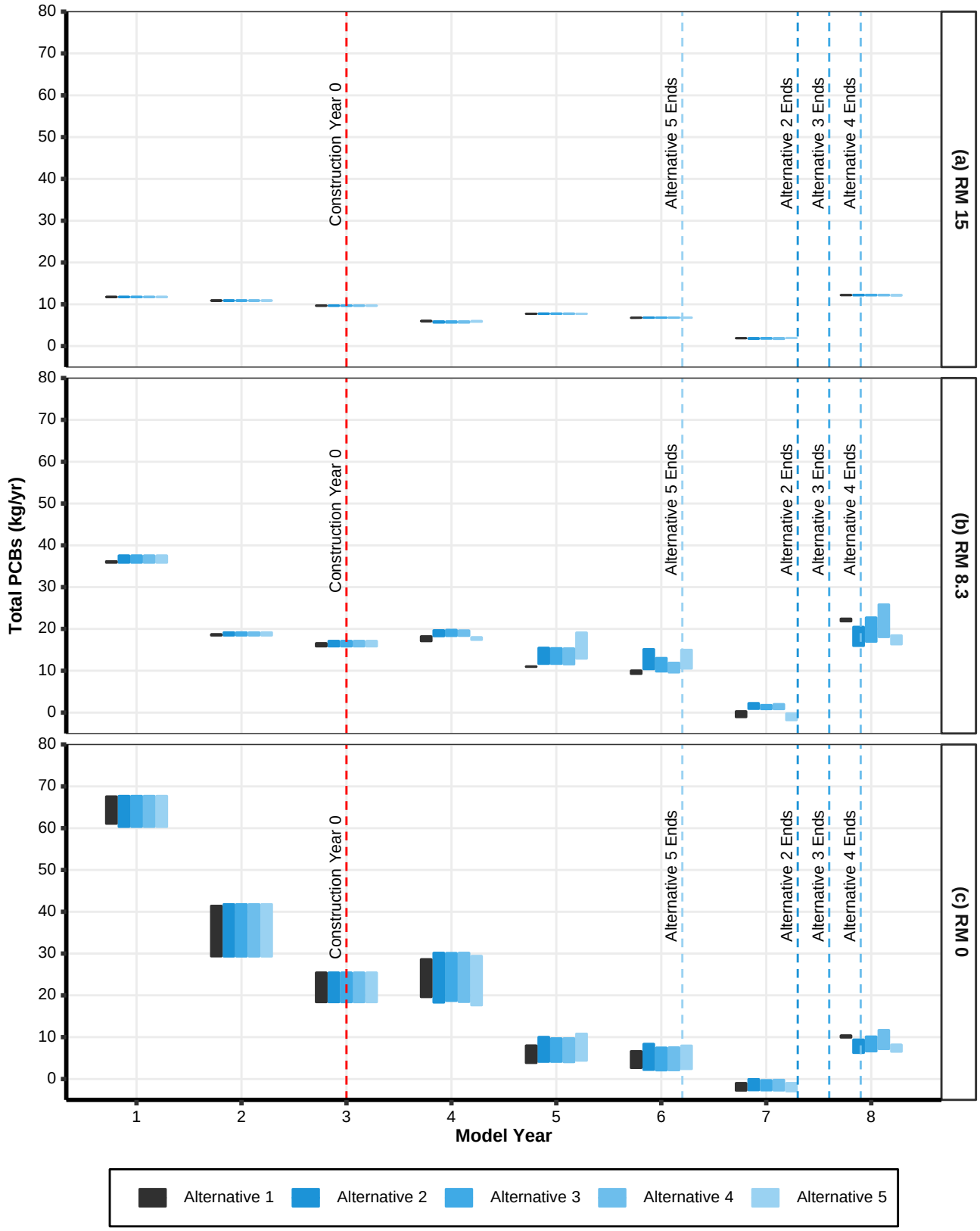
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 8-30.
Projected Annual Water Column Downstream Load of 2,3,7,8-TCDD at (a) RM 15, (b) RM 8.3, (c) RM 0 during Pre-IR Completion Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



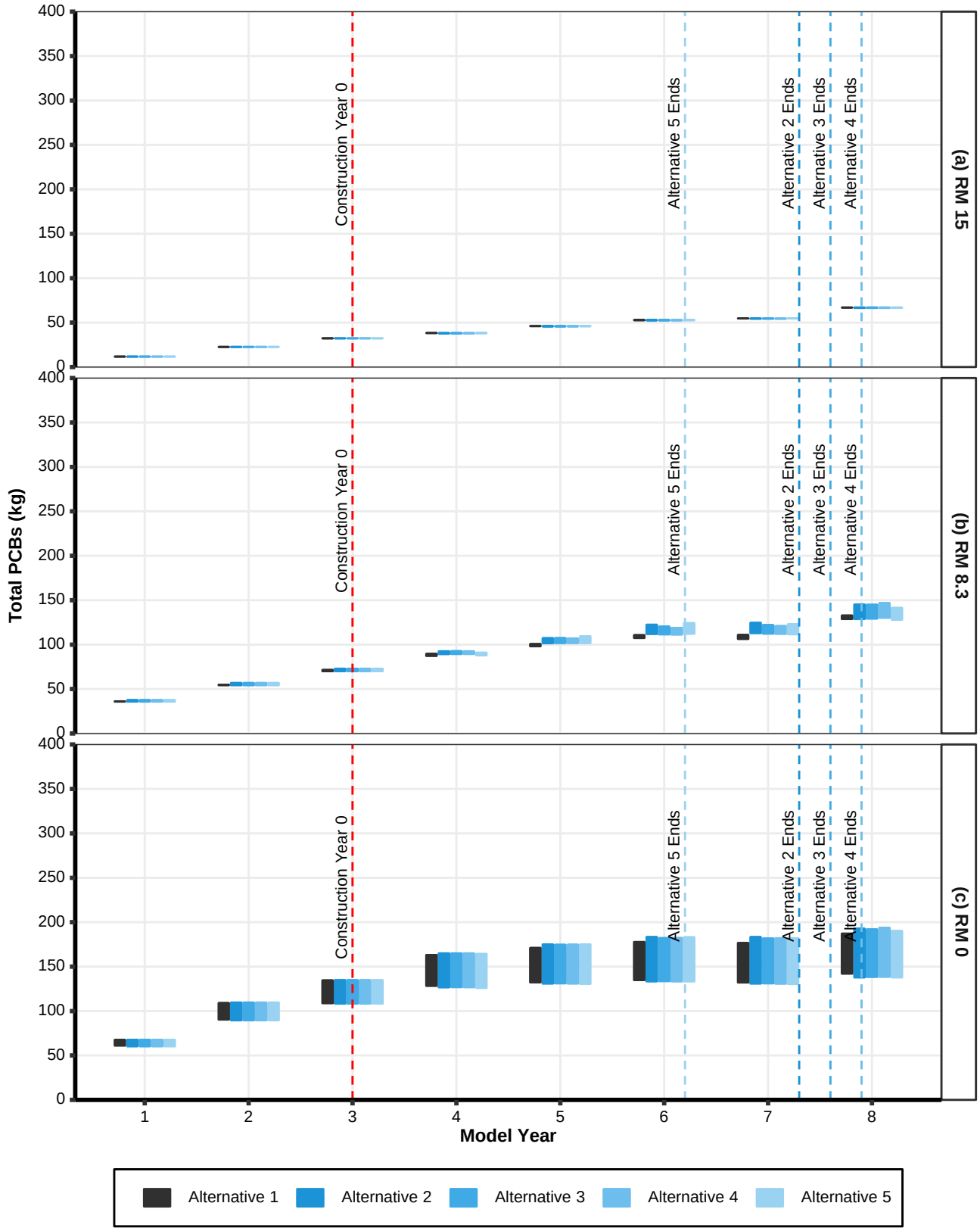
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 8-31.
Projected Cumulative Water Column Downstream Load of 2,3,7,8-TCDD at (a) RM 15, (b) RM 8.3, (c) RM 0 during Pre-IR Completion Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



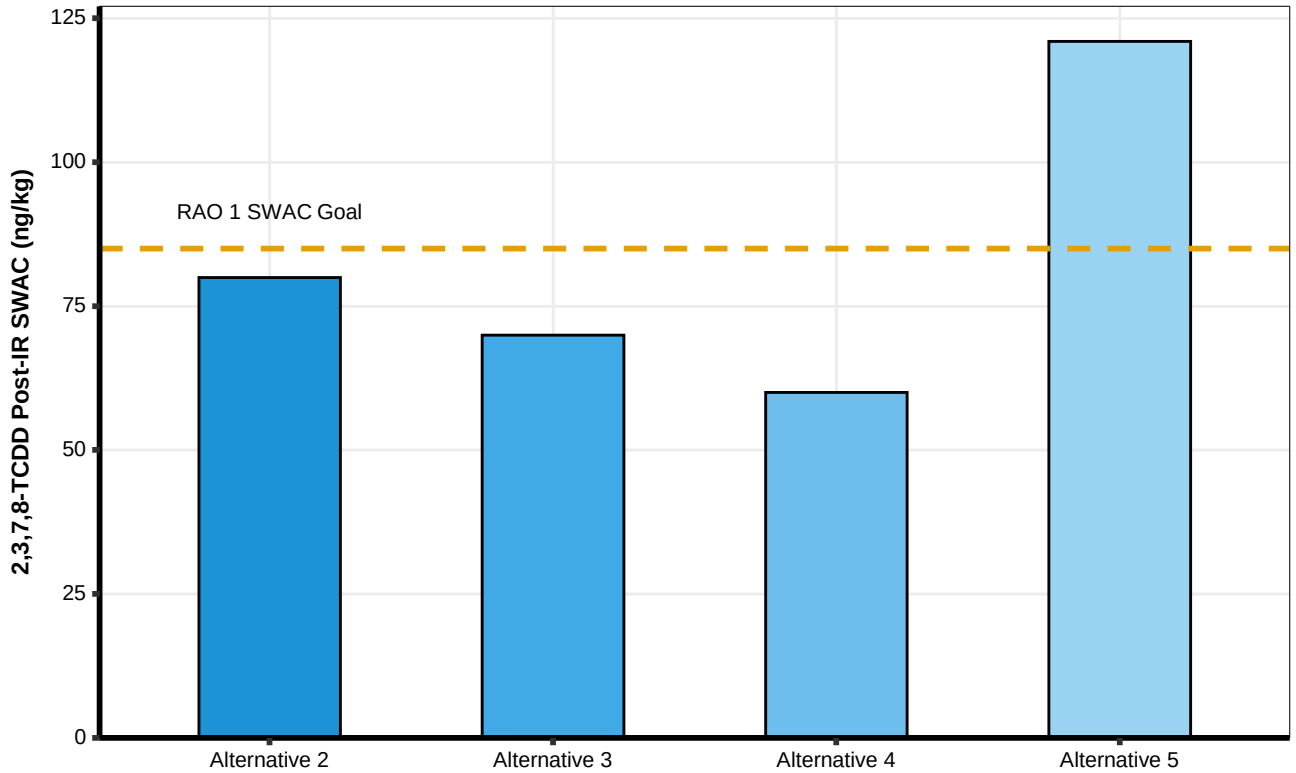
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

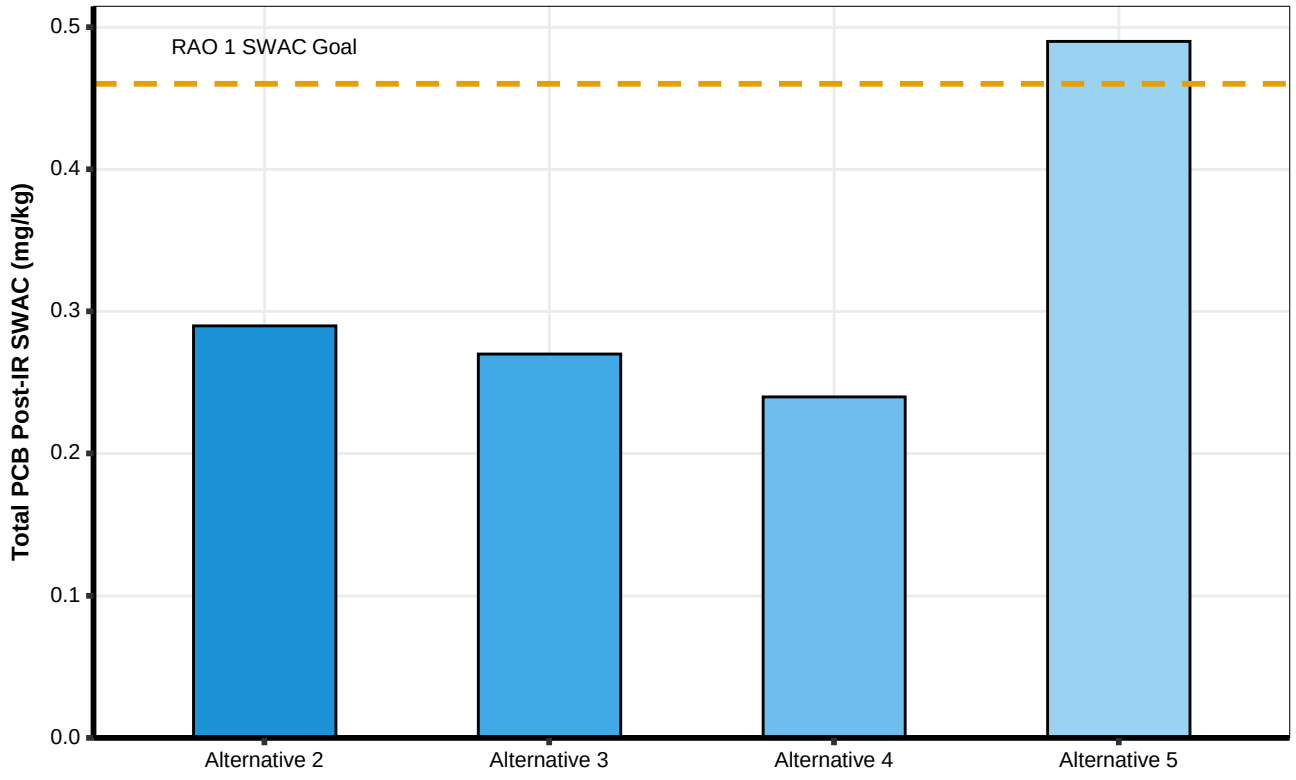
Figure 8-32.
Projected Annual Water Column Downstream Load of Total PCBs at (a) RM 15, (b) RM 8.3, (c) RM 0 during Pre-IR Completion Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

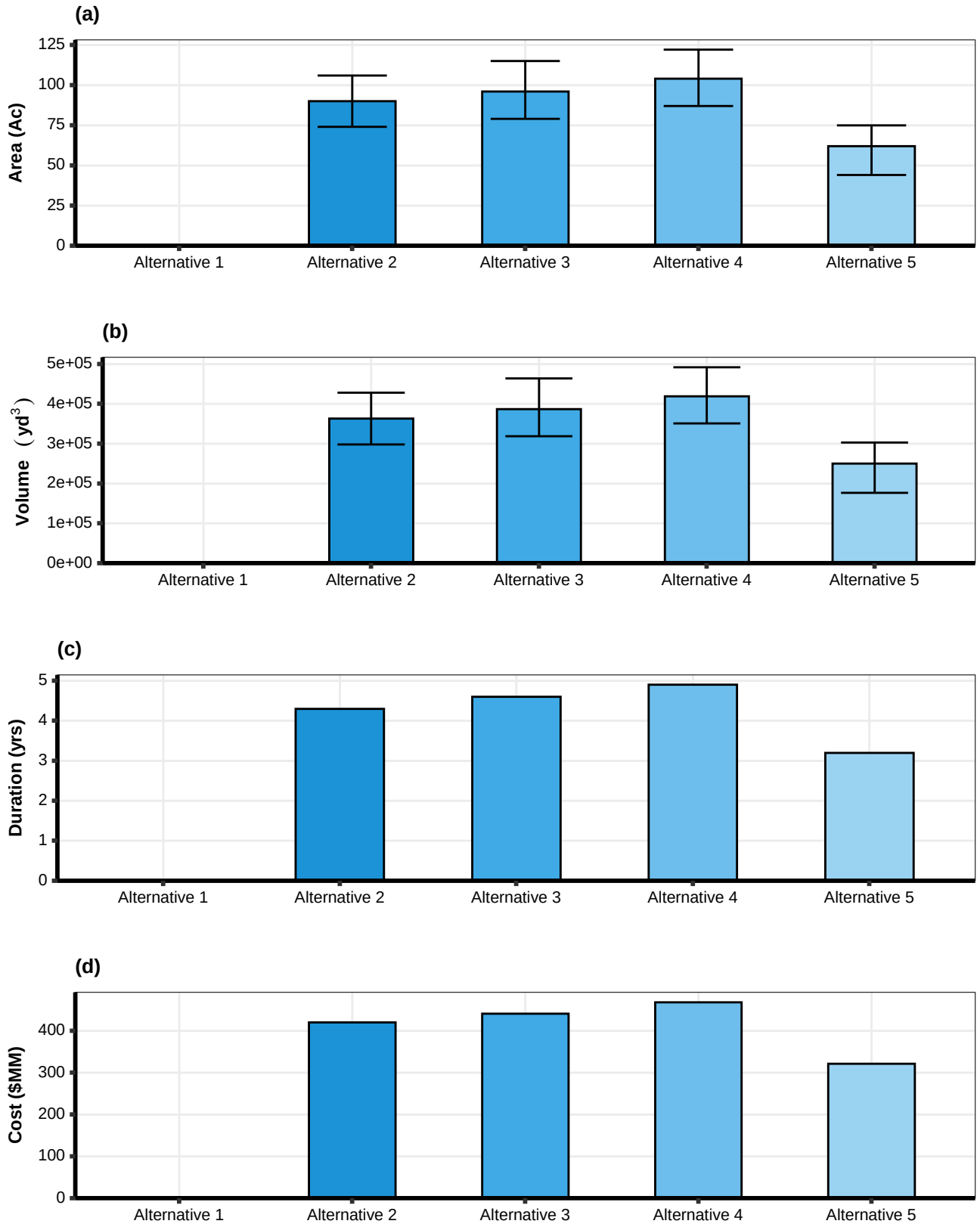
Figure 8-33.
Projected Cumulative Water Column Downstream Load of Total PCBs at (a) RM 15, (b) RM 8.3, (c) RM 0 during Pre-IR Completion Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study





Note: Alternative 1 not shown due to scale.

Figure 8-34.
Post-IR SWACs for 2,3,7,8-TCDD and Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note: Bars show variance based on 100 conditional simulation maps (See Section 8.2.1).

Figure 8-35.
(a) Remedial Footprint, (b) Volume Removed, (c) Construction Duration, and (d) Cost for IR Alternatives
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

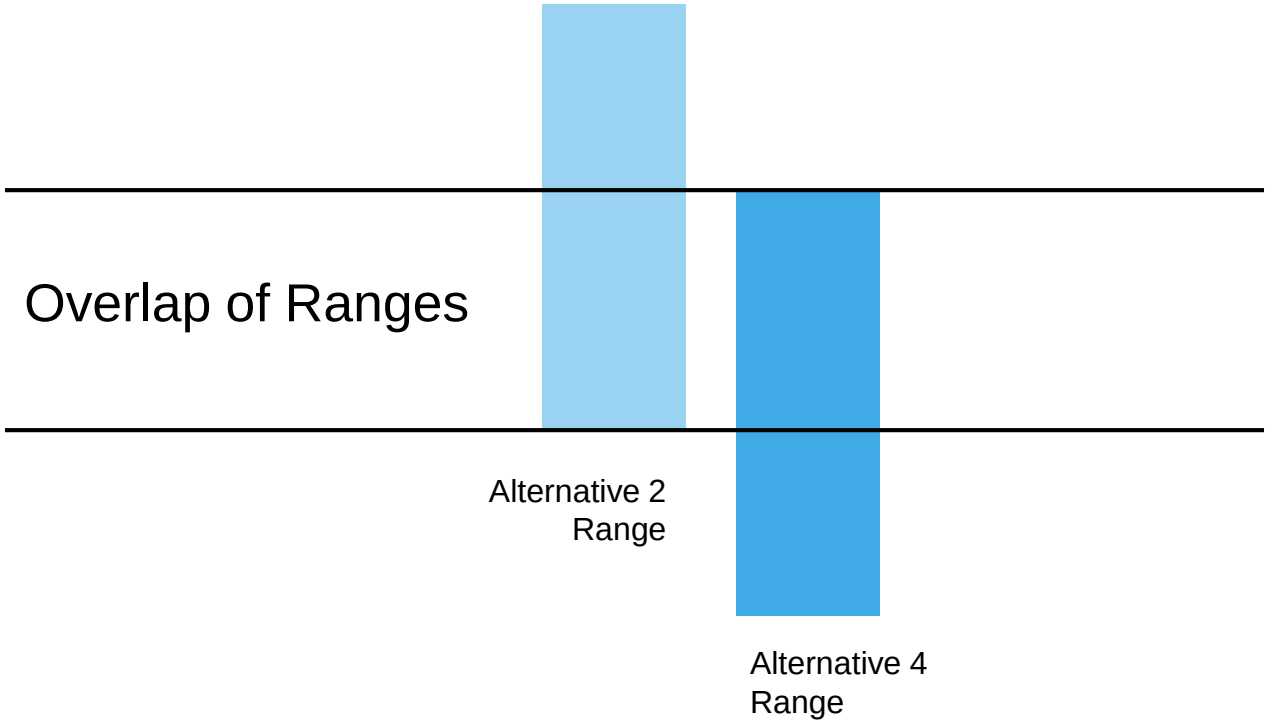
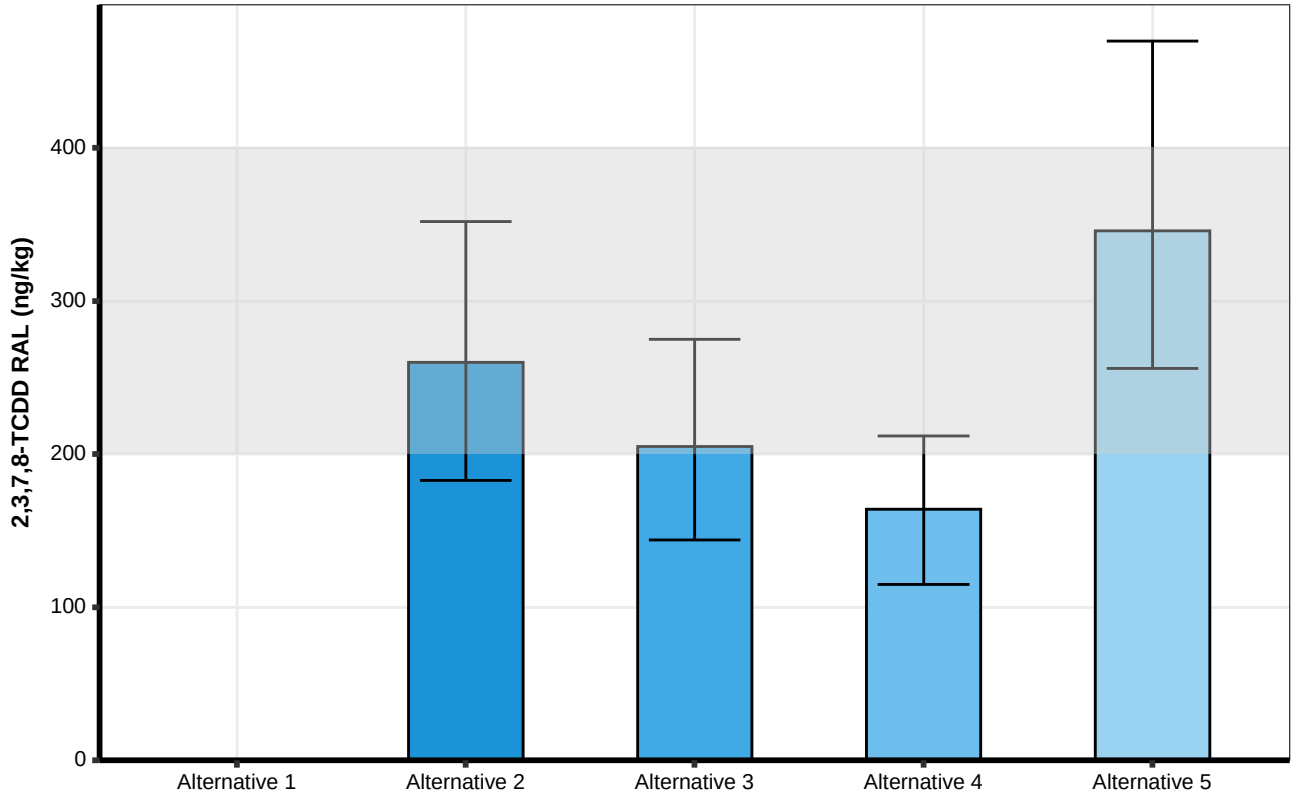
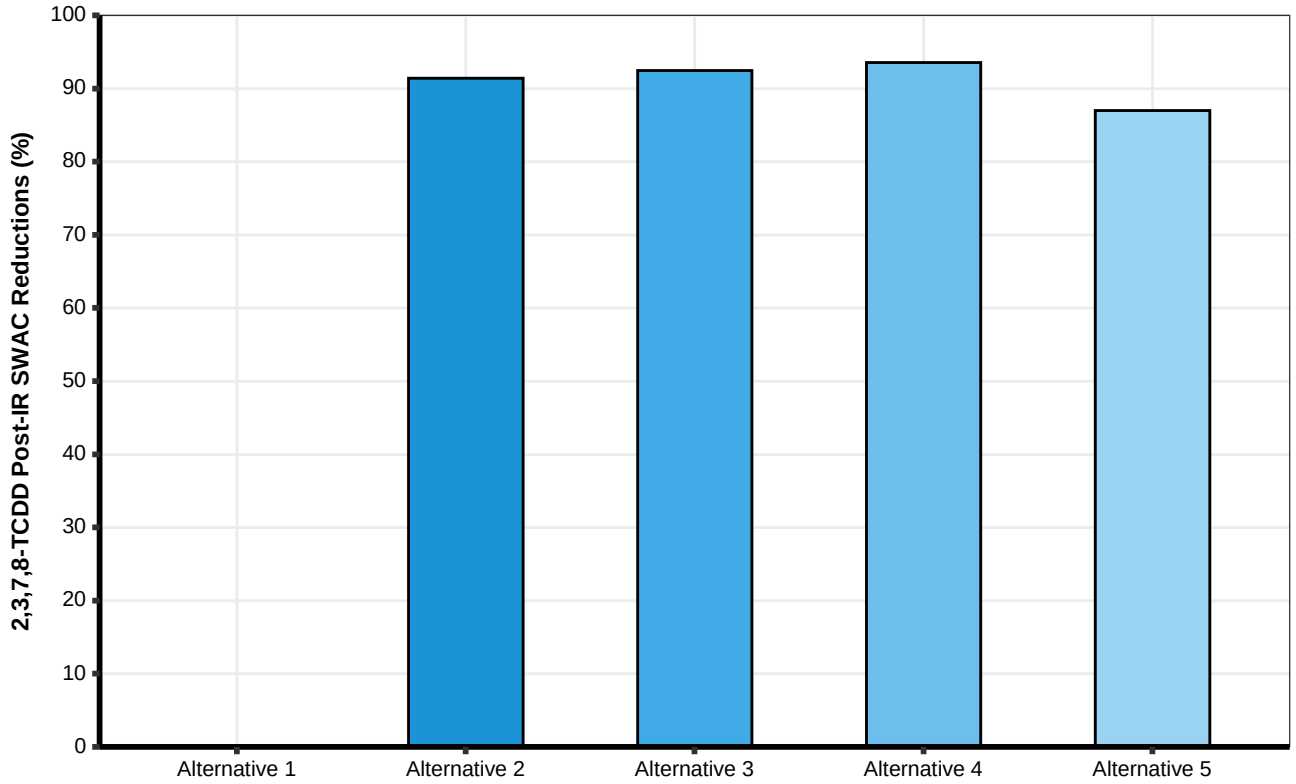


Figure 8-36.
Example of Evaluation of Overlap of Projection Ranges
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



Note: Bars show variance based on 100 conditional simulation maps (See Section 8.2.1). Shaded band indicates the lower range of source sediment concentrations.

Figure 8-37.
2,3,7,8-TCDD RALs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



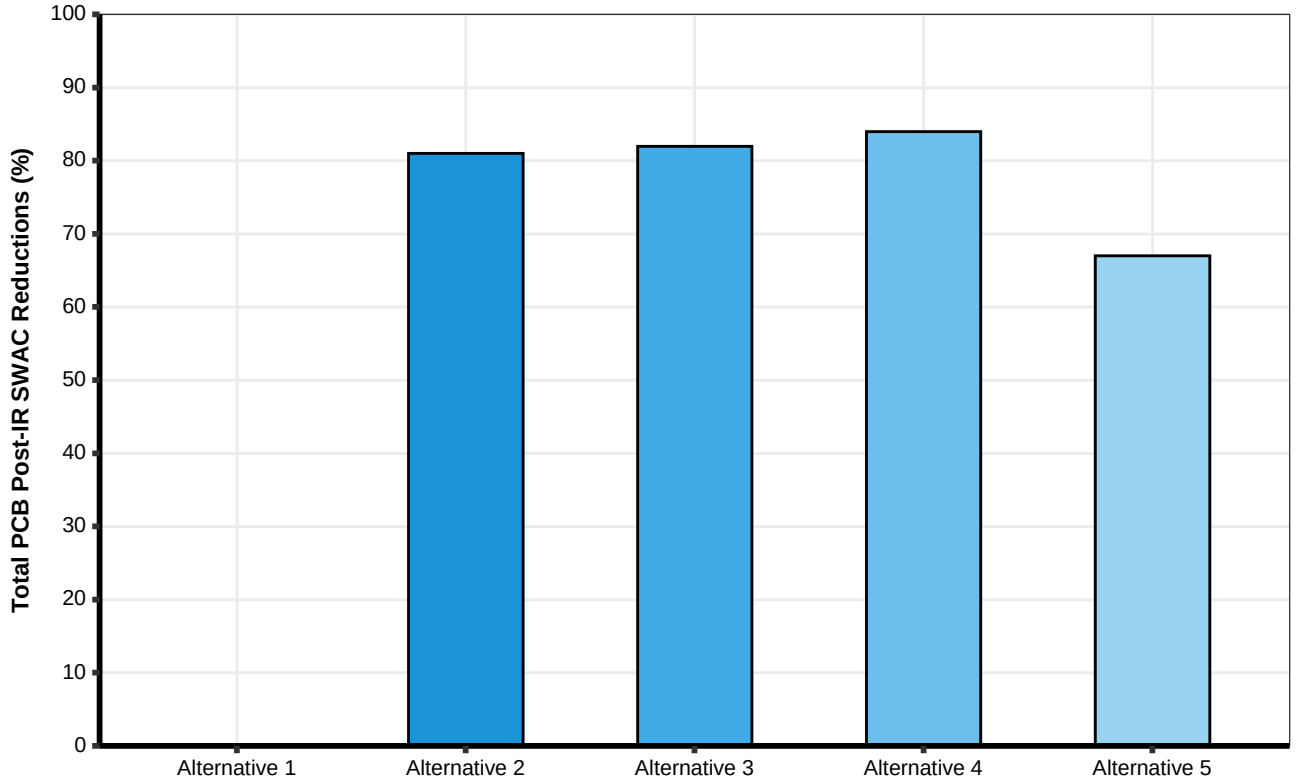
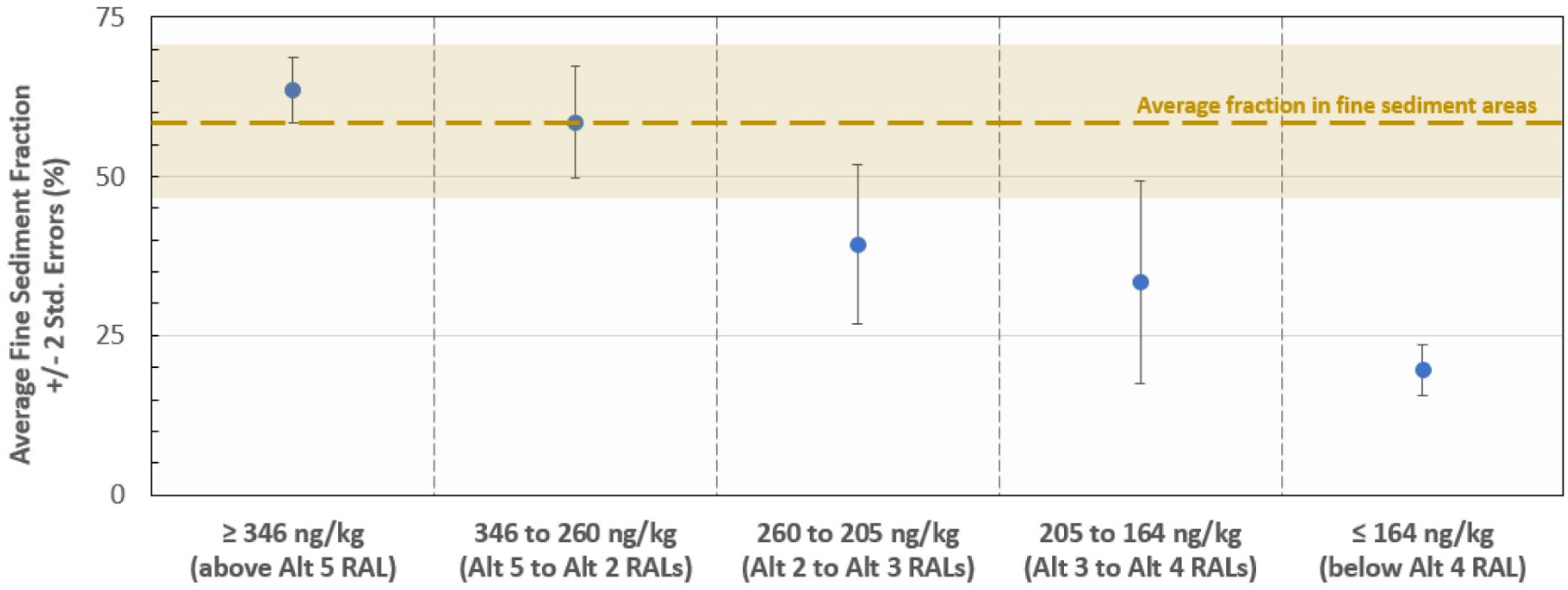


Figure 8-38.
Post-IR SWAC Reductions for 2,3,7,8-TCDD and Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Average fine sediment fraction of surface samples from RM 8.3 to RM 15 with 2,3,7,8-TCDD concentration within bins defined by the RALs for the FS alternatives as delineated on the FS base map (CS 37).
The dashed line indicates the mean fine sediment fraction of samples collected in areas designated to be fine sediments by both the RI/FS definition (based mainly on the 2005 side-scan sonar survey) and the 2019 side-scan sonar survey. The yellow band indicates two standard errors about that mean.

Figure 8-39.
Average Fine Sediment Fraction in Incremental Area between Alternatives
Upper 9-Mile Source Control Interim Remedy and Feasibility Study
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

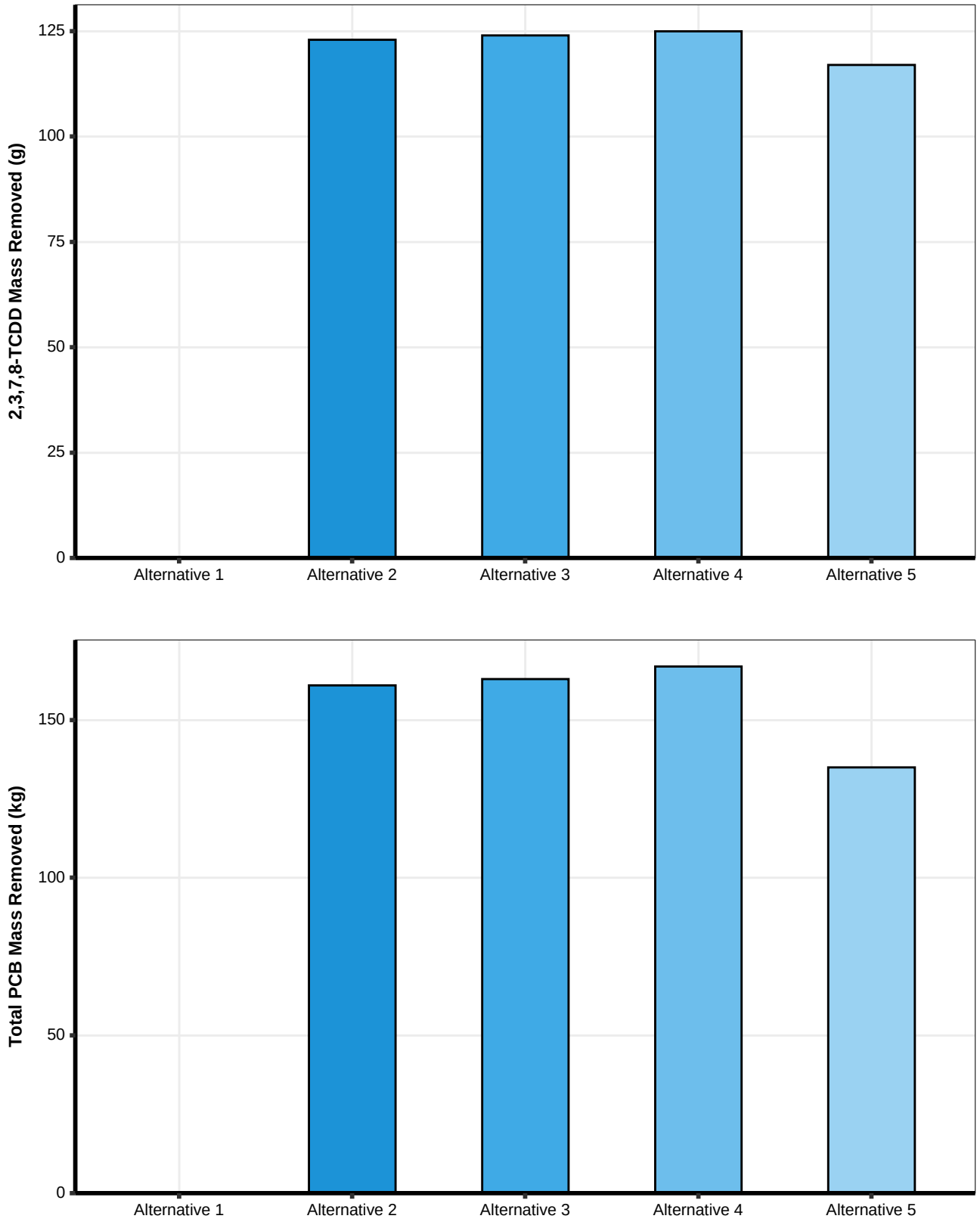
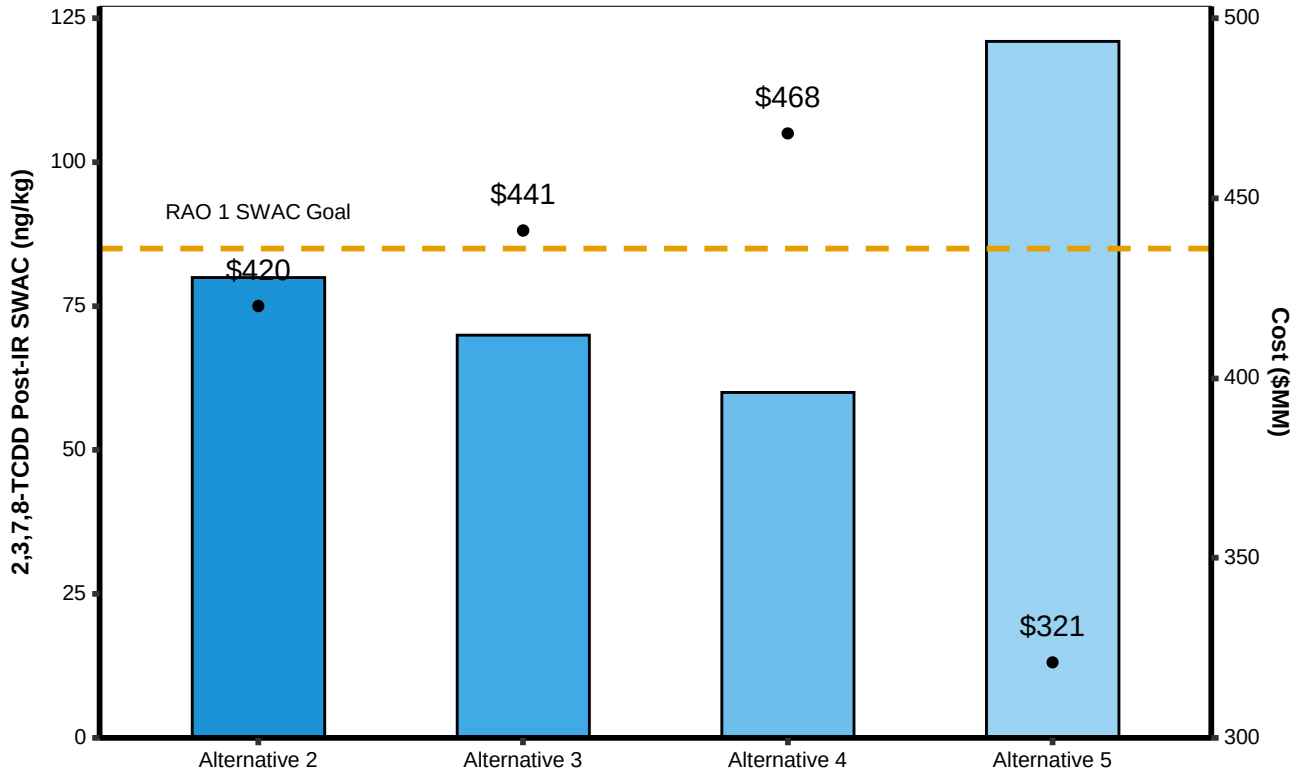
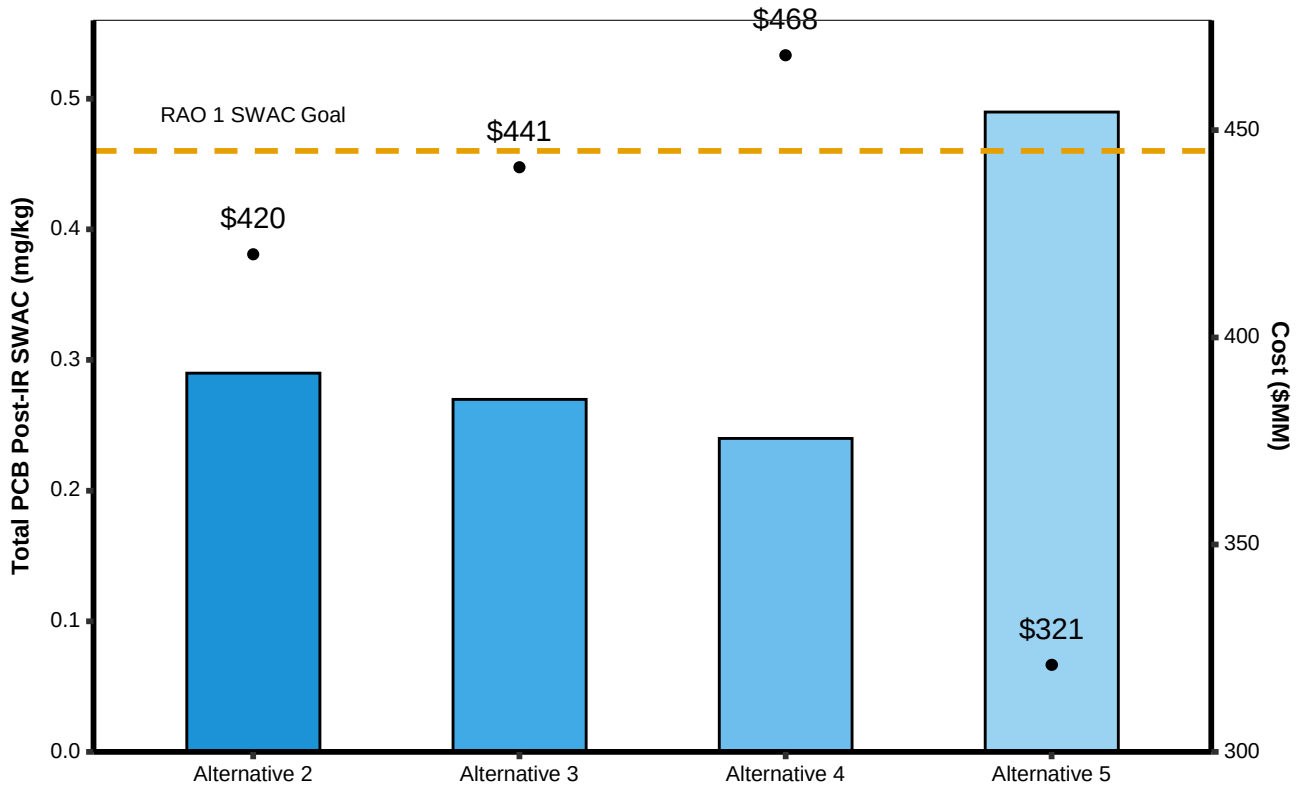


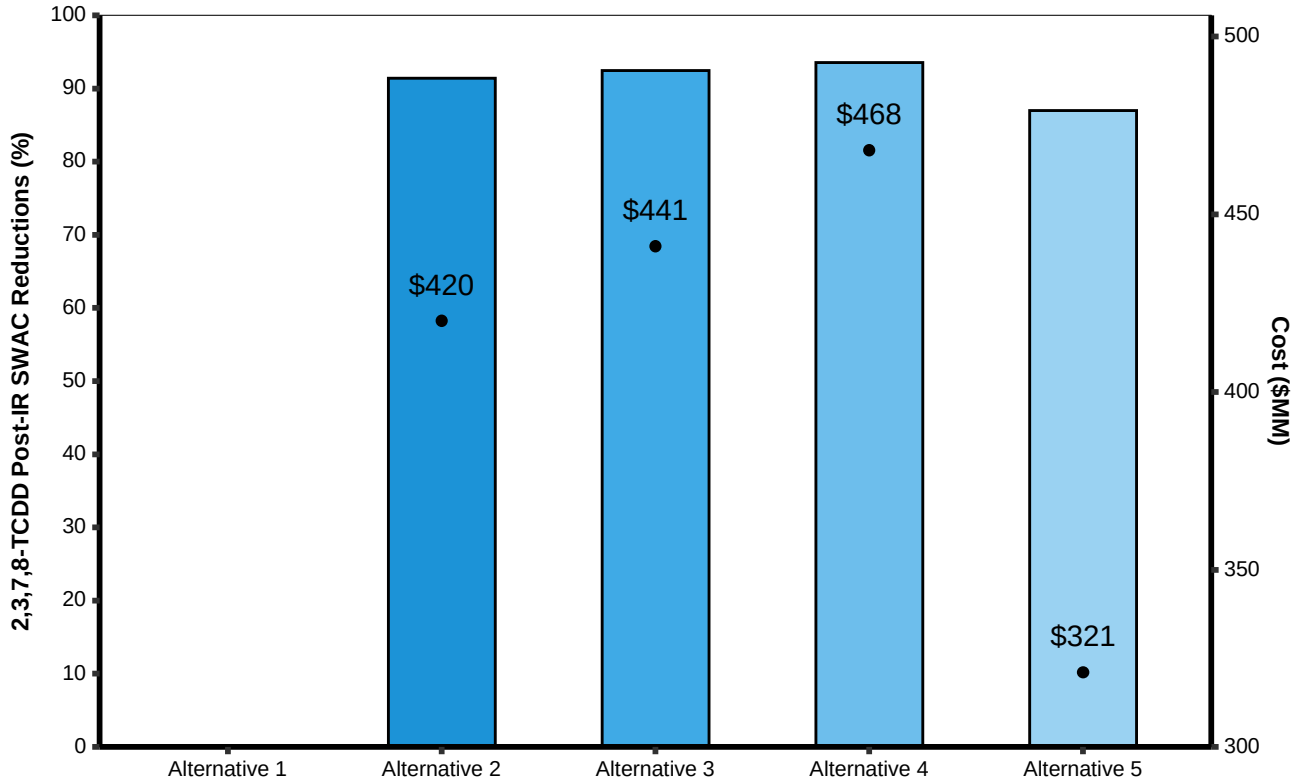
Figure 8-40.
Mass of 2,3,7,8-TCDD and Total PCBs Removed from the Upper 0.5 ft of the Sediment Bed
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

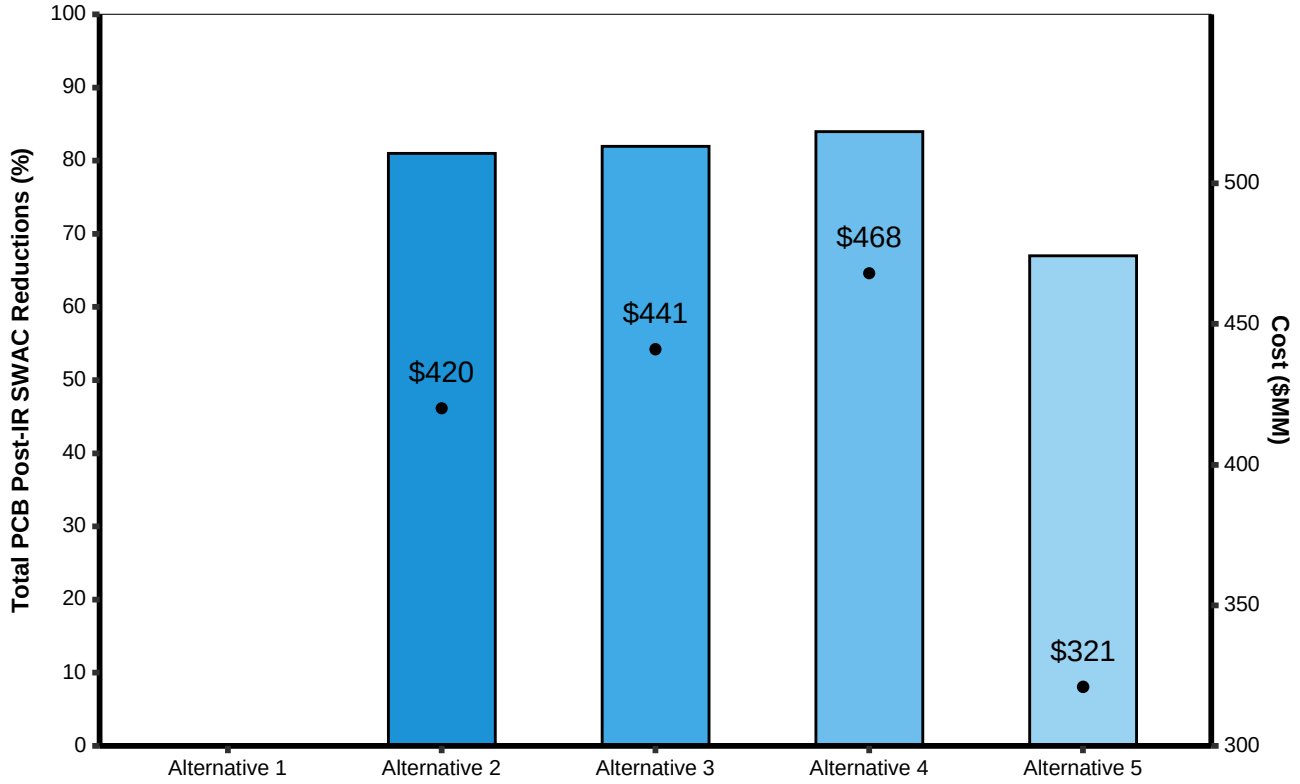




Note: Alternative 1 not shown due to scale.

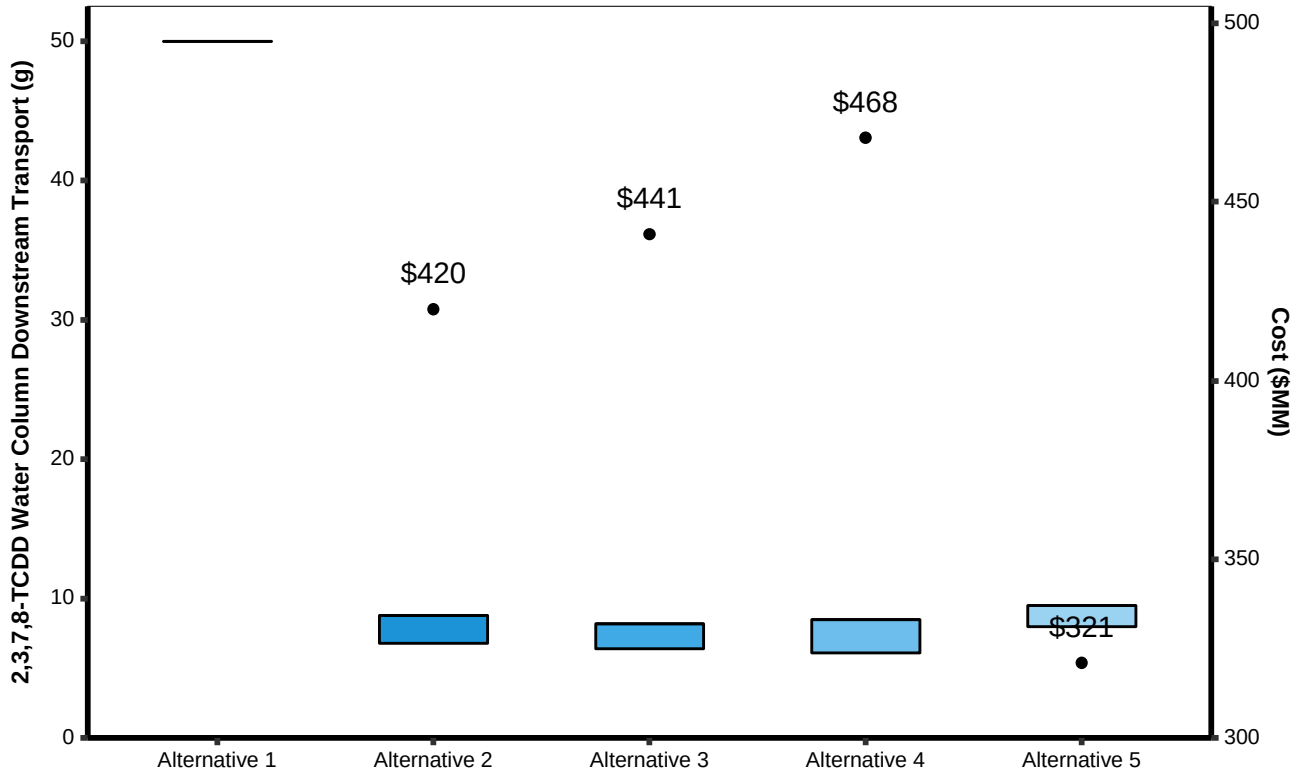
Figure 8-41.
Cost Versus Post-IR SWACs for 2,3,7,8-TCDD and Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

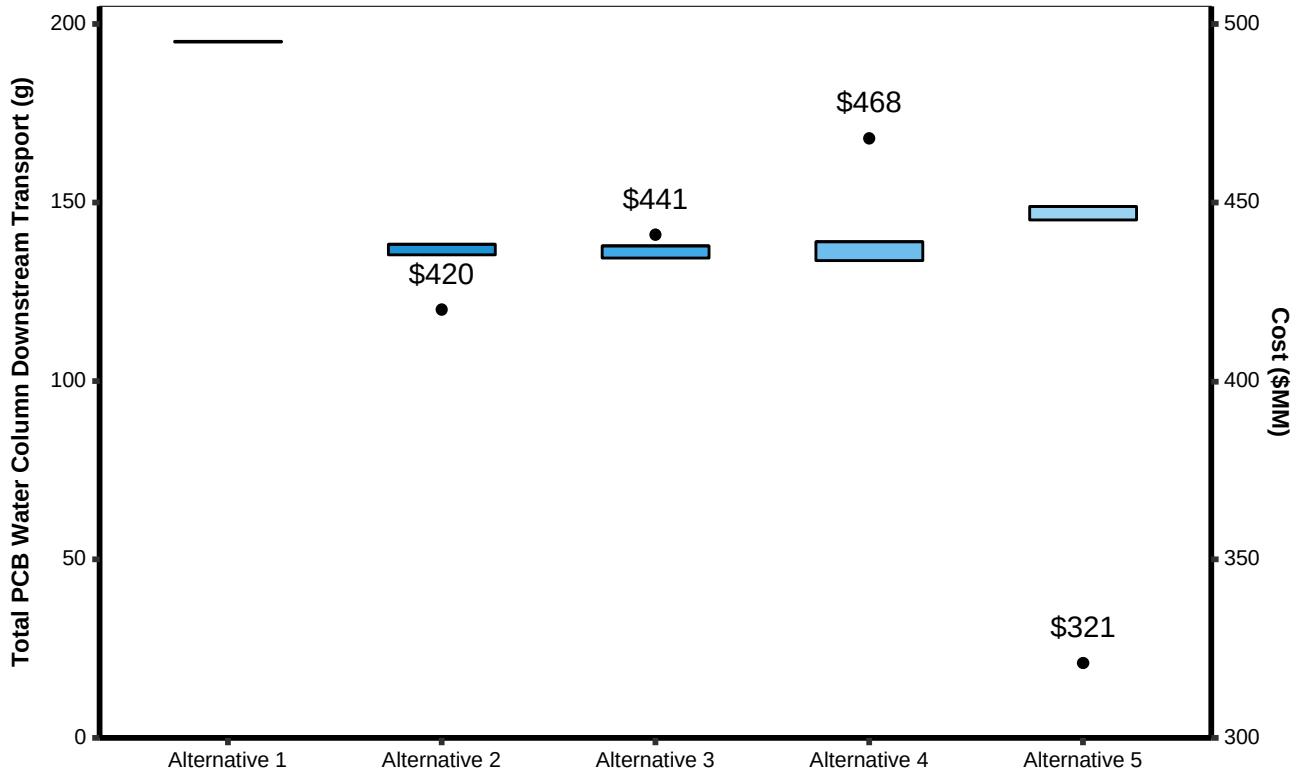




Note: Costs of Alternative 1 are $0.

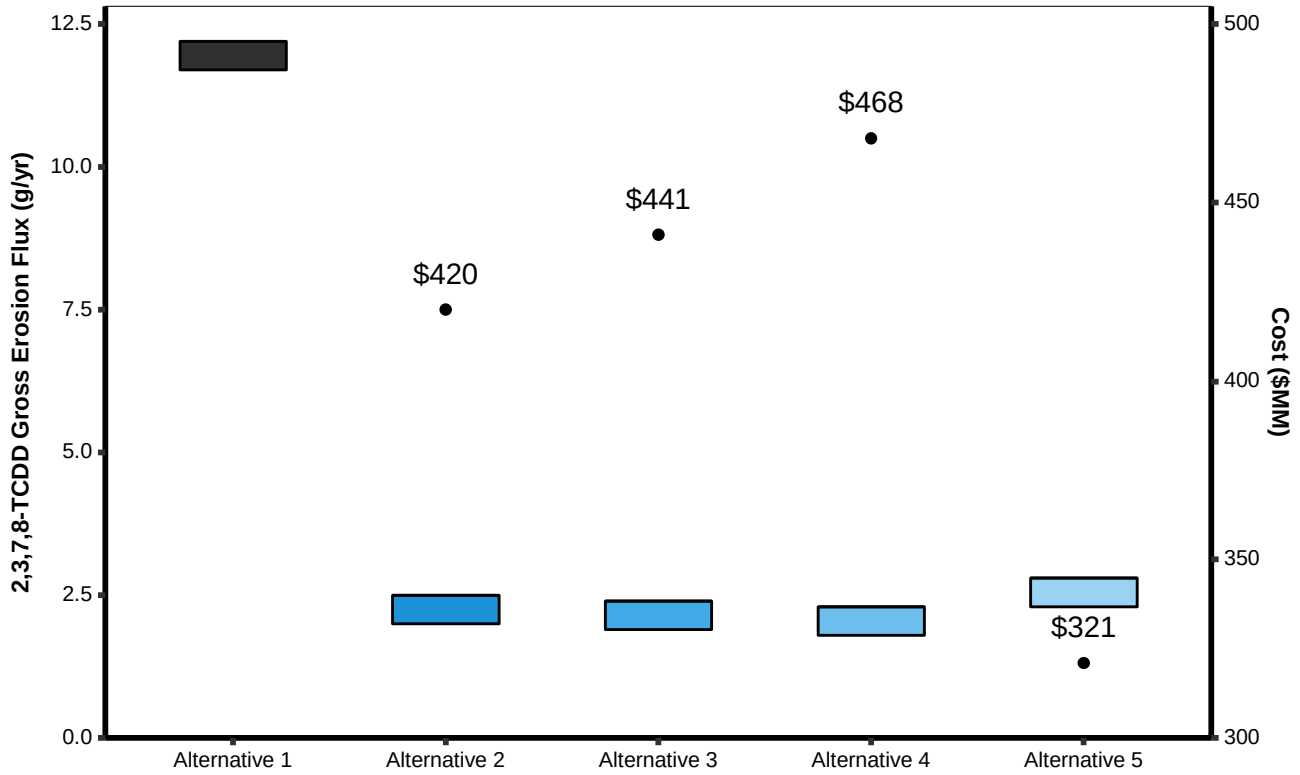
Figure 8-42.
Cost Versus Post-IR SWAC Reductions for 2,3,7,8-TCDD and Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

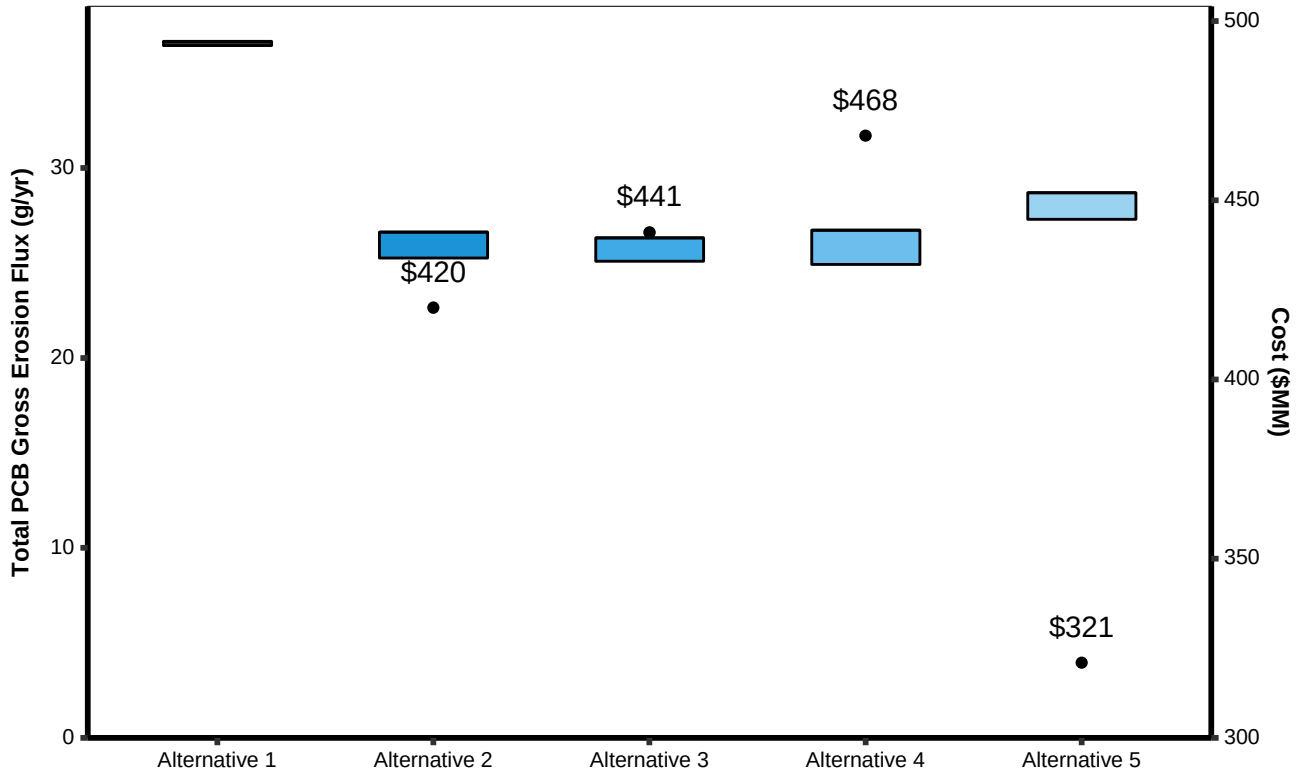




Note: Costs of Alternative 1 are $0.

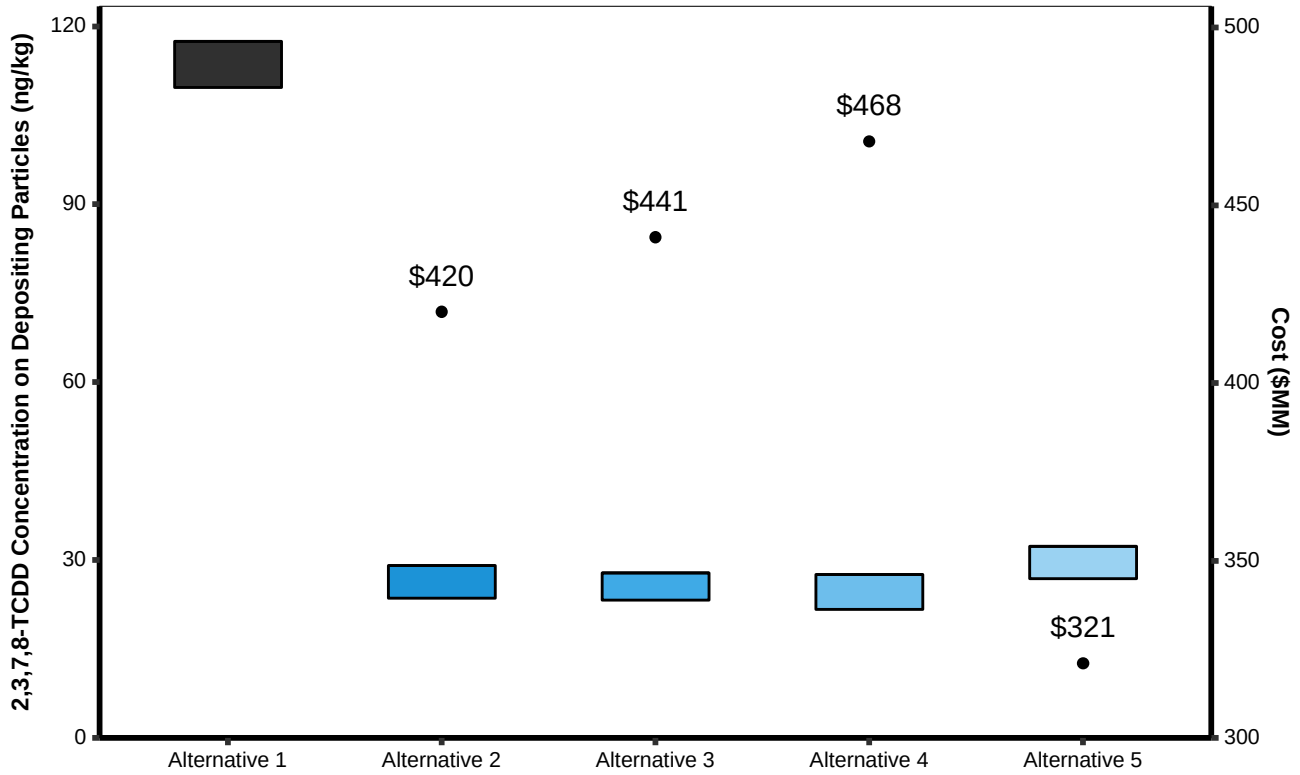
Figure 8-43.
Cost Versus Projected Water Column Downstream Load at RM 8.3,
Year 10 Post-IR Construction Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

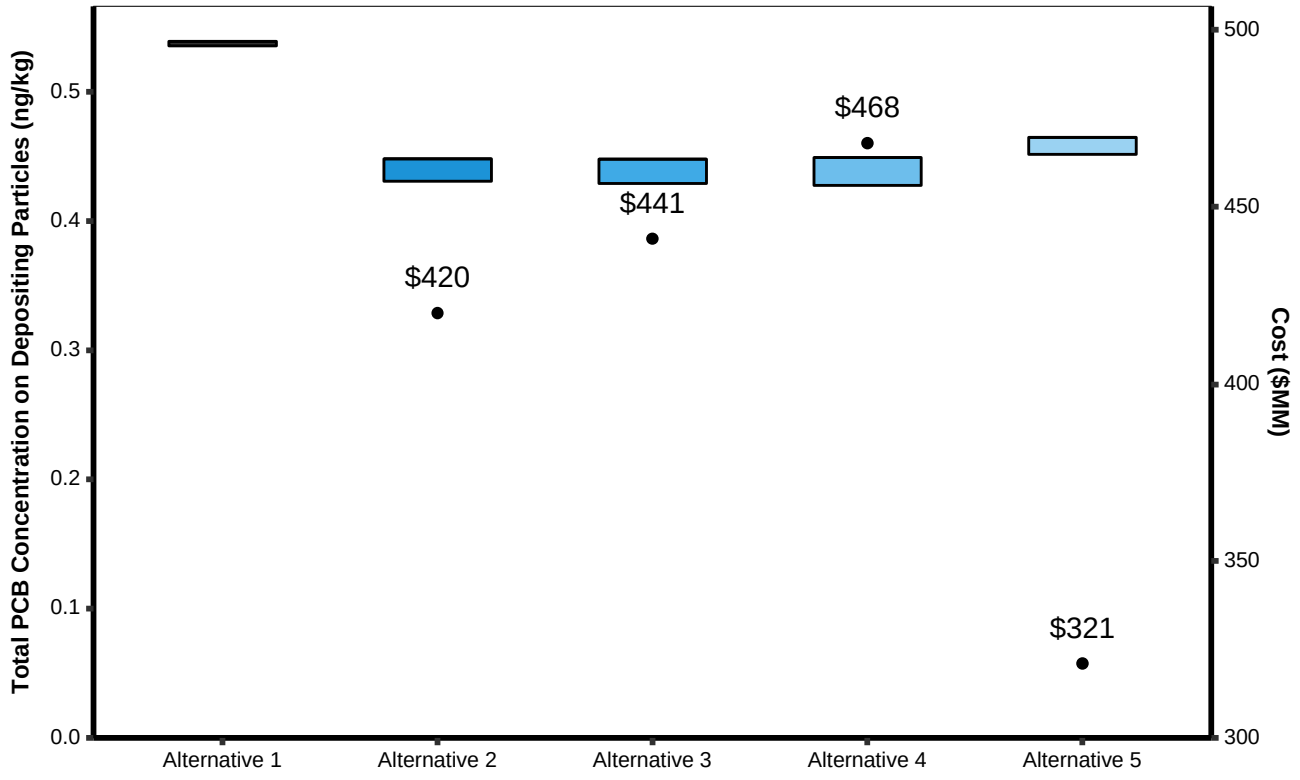




Note: Costs of Alternative 1 are $0.

Figure 8-44.
Cost Versus Projected Erosion Flux, Average over 10-year Post-IR Construction Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study





Note: Costs of Alternative 1 are $0.

Figure 8-45.
Cost Versus Projected Concentration on Depositing Fine Sediment,
Average over 10-year Post-IR Construction Period
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

Tables

Table ES-1. Summary of Preliminary Human Health COCs and Associated Risk

		RME				CTE		
Receptor	Medium	Cancer Risk	Preliminary COCs	Total HI	Preliminary COCs	Cancer Risk	Total HI	Preliminary COCs
RM 0–17								
Angler [a]	Mixed fish diet	4E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Heptachlor Epoxide, 4,4'-DDD, 4,4'-DDE, *cis*-Chlordane, *gamma*-Chlordane, Hexachlorobenzene	193	**TCDD-TEQ**, **PCBs**, **Mercury**, 4,4'-DDE, Dieldrin, Heptachlor Epoxide *trans*-Nonachlor	≤1E-4	15	**TCDD-TEQ**, **PCBs**
	Crab	1E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Arsenic, 4,4'-DDE, Heptachlor Epoxide	50	**TCDD-TEQ**, **PCBs**	≤1E-4	8	**TCDD-TEQ**, PCBs
RM 6–9								
Angler [a]	Mixed fish diet	4E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Heptachlor Epoxide, 4,4'-DDD, 4,4'-DDE, *cis*-Chlordane, *gamma*-Chlordane, Hexachlorobenzene	193	**TCDD-TEQ**, **PCBs**, **Mercury**, 4,4'-DDE, Dieldrin, Heptachlor Epoxide *trans*-Nonachlor	≤1E-4	15	**TCDD-TEQ**, **PCBs**
	Crab	1E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Arsenic, 4,4'-DDE, Heptachlor Epoxide	50	**TCDD-TEQ**, **PCBs**	≤1E-4	8	**TCDD-TEQ**, PCBs
Swimmer (child)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	≤1	
Swimmer (adolescent)	Accessible sediment	≤1E-4		3	**TCDD-TEQ**	≤1E-4	≤1	
Wader (child)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	≤1	
Wader (adolescent)	Accessible sediment	≤1E-4		3	**TCDD-TEQ**	≤1E-4	≤1	
Worker (adult)	Accessible sediment	≤1E-4		2	**TCDD-TEQ**	≤1E-4	≤1	
RM 6–9, East Bank								
Angler [a]	Mixed fish diet	4E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Heptachlor Epoxide, 4,4'-DDD, 4,4'-DDE, *cis*-Chlordane, *gamma*-Chlordane, Hexachlorobenzene	193	**TCDD-TEQ**, **PCBs**, **Mercury**, 4,4'-DDE, Dieldrin, Heptachlor Epoxide *trans*-Nonachlor	≤1E-4	15	**TCDD-TEQ**, **PCBs**
	Crab	1E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Arsenic, 4,4'-DDE, Heptachlor Epoxide	50	**TCDD-TEQ**, **PCBs**	≤1E-4	8	**TCDD-TEQ**, PCBs
Swimmer (child)	Accessible sediment	≤1E-4		6	**TCDD-TEQ**	≤1E-4	2	**TCDD-TEQ**
Swimmer (adolescent)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	2	**TCDD-TEQ**
Wader (child)	Accessible sediment	≤1E-4		5	**TCDD-TEQ**	≤1E-4	2	**TCDD-TEQ**
Wader (adolescent)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	≤1	
Worker (adult)	Accessible sediment	≤1E-4		3	**TCDD-TEQ**	≤1E-4	≤1	

Notes: COCs shown in bold exceed risk of 1E-04 and/or hazard index of 1.

COC = chemical of concern
CTE = central tendency exposure
HI = hazard index
PCB = polychlorinated biphenyl
RME = reasonable maximum exposure
TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ = toxicity equivalence

[a] Table presents the highest calculated risk/hazard for the angler age groups evaluated in the BHHRA (combined adult/child for cancer and young child for noncancer).

Table ES-2. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
Metals						
Arsenic	*tissue:* worm (2.2) blue crab (2.2)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Cadmium	*no unacceptable risk*	*diet:* mummichog (1.3) common carp (1.2) white perch (1.1) white sucker (1.2) American eel (0.70–1.2)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Chromium	*tissue:* worm (6.0) mussel (3.7)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (160)	*no unacceptable risk*
Copper	*surface water:* estuarine (0.14–2.7) freshwater (0.034–1.0) *tissue:* blue crab (2.1)	*surface water:* estuarine (0.14–2.7) freshwater (0.023–1.0) *tissue:* mummichog (2.1) other forage fish (2.7) white perch (9.3) American eel (1.7)	*diet:* spotted sandpiper (0.30–3.6) great blue heron (0.029–1.3)	*no unacceptable risk*	*sediment* (2.4) *surface water* (estuarine: 1.8)	*surface water:* estuarine (0.14–2.7) freshwater (0.023–1.0)
Lead	*tissue:* worm (0.16–2.5)	*no unacceptable risk*	*diet:* spotted sandpiper (0.20–10) belted kingfisher (0.015–1.1)	*no unacceptable risk*	*sediment* (2.3)	*no unacceptable risk*
Methylmercury/mercury	*tissue:* blue crab: (1.3–1.5)	*tissue:* white catfish (0.71–1.1); American eel (0.74–1.1); largemouth bass (1.5–2.6); smallmouth bass (0.63–1.1) *egg tissue:* mummichog (0.11–1.1) *diet*: mummichog (1.3) common carp (1.1) white perch (1.3) white catfish (1.1) American eel (1.1–1.3)	*diet:* great blue heron (0.031–1.6) belted kingfisher (0.13–1.6)	*no unacceptable risk*	*sediment* (9.7)	*no unacceptable risk*
Nickel	*tissue:* worm (12) mussel (6.0)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Selenium	*tissue:* worm (1.1) blue crab (1.5)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (1.8)	*no unacceptable risk*
Silver	*tissue:* blue crab (1.0)	*no unacceptable risk*	*not evaluated (no toxicity data available)*	*not evaluated (no toxicity data available)*	*no unacceptable risk*	*no unacceptable risk*

Table ES-2. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
Vanadium	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (14)	*no unacceptable risk*
Zinc	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (3.1) *surface water*: estuarine (21)	*no unacceptable risk*
Organometals						
TBT	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*surface water:* estuarine (1.1) freshwater (50)	*no unacceptable risk*
PAHs						
HPAHs	*tissue:* worm (0.090–3.0)	*no unacceptable risk*	*diet*: spotted sandpiper (1.9–10)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
PCBs						
Total PCBs	*tissue:* worm (0.46–14.1) blue crab (0.67–21) mussel (0.046–1.4)	*tissue:* mummichog (0.16–1.1) other forage fish (0.14–1.0) common carp (1.4–9.8) white perch (0.66–4.7) channel catfish (0.45–3.2) brown bullhead (0.37–2.6) white catfish (0.89–6.4) white sucker (0.76–5.5) American eel (0.53–3.8) largemouth bass (2.1–15) northern pike (0.53–3.8) smallmouth bass (0.37–2.6) *egg tissue:* mummichog (2.2–18) *diet:* northern pike (1.3)	*diet:* spotted sandpiper (0.047–1.2) great blue heron (0.031–1.1) *egg tissue:* great blue heron (0.078–284) belted kingfisher (0.22–76)	*diet:* mink (0.94–3.1) river otter (2.6–3.7)	*no unacceptable risk*	*no unacceptable risk*
PCB TEQ	*no unacceptable risk*	*tissue:* common carp (0.037–2.4) white perch (0.018–1.2) channel catfish (0.015–1.0) white catfish (0.029–1.9) white sucker (0.027–1.8) largemouth bass (0.14–9.4) northern pike (0.019-1.3) *diet:* white perch (1.0) American eel (0.95–1.8) largemouth bass (1.6) smallmouth bass (1.5) northern pike (2.1)	*diet:* spotted sandpiper (0.073–3.9) great blue heron (0.030–1.6) belted kingfisher (0.10–1.5) *egg tissue:* great blue heron (0.56–36) belted kingfisher (0.46–12)	*diet:* mink (0.12–1.1) river otter (0.31–1.4)	*not evaluated*	*not evaluated*

Table ES-2. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
PCDD/PCDFs						
2,3,7,8-TCDD	*surface water:* estuarine (0.0028–4.3) *tissue:* worm (0.013–29) blue crab (0.019–44) mussel (0.00073–1.7)	*tissue:* mummichog (0.41–27) other forage fish (0.38–26) common carp (5.1–340) white perch (1.6–110) channel catfish (0.80–53) brown bullhead (1.3–83) white catfish (1.8–120) white sucker (1.1–72) American eel (0.19–13) largemouth bass (1.5–100) northern pike (0.79–53) smallmouth bass (0.63–42)	*not evaluated*	*not evaluated*	*no unacceptable risk*	*no unacceptable risk*
PCDD/PCDF TEQ	*tissue:* worm (0.013–29) blue crab (0.021–48) mussel (0.00077–1.8)	*tissue:* mummichog (0.43–28) other forage fish (0.41–27) common carp (5.2–340) white perch (1.7–110) channel catfish (0.83–56) brown bullhead (1.3–89) white catfish (1.8–120) white sucker (1.1–72) American eel (0.20–13) largemouth bass (1.5–100) northern pike (0.83–56) smallmouth bass (0.63–42) *diet*: mummichog (200) common carp (200) white perch (170) channel catfish (190) white catfish (160) white sucker (190) American eel (180–190) largemouth bass (150) smallmouth bass (140) northern pike (200)	*diet:* spotted sandpiper (0.014–21) great blue heron (0.020–1.9) belted kingfisher (0.090–1.9) *egg tissue:* great blue heron (0.42–37) belted kingfisher (0.38–14)	*diet:* mink: (0.79–8.7) river otter (1.8–10)	*not evaluated*	*not evaluated*

Table ES-2. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
Total TEQ	*tissue:* worm (0.013–30) blue crab (0.021–48) mussel (0.00077–1.8)	*tissue:* mummichog: (0.43–28) other forage fish (0.41–27) common carp (5.2–340) white perch (1.7–110) channel catfish (0.83–56) brown bullhead (1.3–89) white catfish (1.9–130) white sucker (1.1–72) American eel (0.21–14) largemouth bass (1.5–100) northern pike (0.92–61) smallmouth bass (0.68–46) *diet:* mummichog (210) common carp (200) white perch (170) channel catfish (190) white catfish (160) white sucker (190) American eel (190–200) largemouth bass (150) smallmouth bass (140) northern pike (200)	*diet:* spotted sandpiper (0.089–25) great blue heron (0.044–3.5) belted kingfisher (0.18–3.1) *egg tissue:* great blue heron (1.0–74) belted kingfisher (0.85–23)	*diet:* mink (1.0–9.9) river otter (2.4–12)	*not evaluated*	*not evaluated*
Pesticides						
Total DDx	*tissue:* worm (0.12–1.6) blue crab (0.52–6.8)	*tissue* : common carp (1.3–1.7)	*diet:* spotted sandpiper (0.018–1.4) great blue heron (0.020–2.4) belted kingfisher (0.066–1.8) *egg tissue:* great blue heron (0.14–18) belted kingfisher (0.37–4.6)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Dieldrin	*no unacceptable risk*	*tissue:* common carp (0.28–1.4) channel catfish (0.24–1.2) American eel (0.27–1.4) largemouth bass (0.20–1.0) northern pike (0.22–1.1)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Other						
Cyanide	*surface water:* estuarine (1.3–4.1) freshwater (0.23–1.0)	*surface water:* estuarine (1.6–5.3)	*not evaluated*	*not evaluated*	*surface water:* estuarine (2.0)	*surface water:* estuarine (1.6–5.3)

Notes:

COC = chemical of concern
COPEC = chemical of potential ecological concern
EF = exceedance factor
DDx = DDT and metabolites
HPAH = high molecular weight polycyclic aromatic hydrocarbon
HQ = hazard quotient
LOAEL = lowest-observed-adverse-effect level
LOE = line of evidence
PCB = polychlorinated biphenyl
PCDD/PCDF = polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran
TBT = tributyltin
TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ = toxicity equivalence
TRV = toxicity reference value

[a] Preliminary COCs are identified as those COPECs with HQs ≥ 1.0 based on any LOE and effect-level concentration (i.e., HQ ≥ 1.0 based on a range of LOAELs for tissue and diet LOEs, HQ ≥ 1.0 based on acute or chronic surface water TRVs; HQ ≥ 1.0 based on plant-specific sediment TRVs).

Table ES-3. Summary of Estimated Areas, Volumes, and Durations of the Alternatives

Alternative	Description	Area (ac)	Volume (cy)[a]	Construction Duration (years)[b]
1	No Action	--	--	--
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	90	363,000	4.3
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	96	387,000	4.6
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	104	419,000	4.9
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	62	250,000	3.2

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

ac = acre

cy = cubic yard

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

[a] Excavation depth assumed to be 2.5 ft, which includes a provision for a 0.5-ft overdredge allowance (Appendix A).

[b] Rate of removal is assumed to be between 476 cy/day and 813 cy/day; variation is based on dredging location and equipment. Construction duration estimates assume 24-hour workdays, six days per week (Appendix A).

Table ES-4. Summary of Cost Estimates

Alternative	Description	Direct Capital ($M) [a]	Indirect Capital ($M)	Total Capital ($M)	Annual OMM ($M/year) [a,b]	Periodic OMM ($M) [a]	Present Value ($M) [c]
1	No Action	0.0	0.0	0.0	0.0	0.0	0.0
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	335	113	448	0.9	50	420
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	357	116	472	0.9	50	441
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	385	119	504	0.9	51	468
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	233	100	333	0.9	47	321

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

M = million

OMM = operation, maintenance, and monitoring

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

Estimates represent a feasibility level of accuracy (+50/-30%).

[a] Direct capital, annual OMM, and periodic costs include 25% contingency.

[b] Annual OMM costs are assumed to begin in Year 5 and extend for 30 years after construction is complete.

[c] Discount rate from EPA guide to developing and documenting cost estimates during the feasibility study (USEPA 2000a).

Table ES-5. Comparative Analysis of Remedial Alternatives

	Alternative 1 [a]	Alternative 2	Alternative 3	Alternative 4	Alternative 5 [a]
KEY METRICS SUMMARY					
Delineated 2,3,7,8-TCDD surficial SWAC achieved based on CS 37 map (ng/kg)[b]	--	80	70	60	121
Delineated total PCB surficial SWAC achieved based on CS 37 map (mg/kg)	--	0.29	0.27	0.24	0.49
Area of removal (ac)	--	90	96	104	62
Volume of removal (cy)	--	363,000	387,000	419,000	250,000
Mass of 2,3,7,8-TCDD removed from the surficial interval (0-0.5 ft) (g)	--	123	124	125	117
Mass of 2,3,7,8-TCDD removed from the dredge prism (0-2.5 ft) (g)	--	590	610	630	530
Mass of total PCBs removed from the surficial interval (0-0.5 ft) (kg)	--	161	163	167	135
Mass of total PCBs removed from the dredge prism (0-2.5 ft) (kg)	--	810	840	860	630
Total water column load of 2,3,7,8-TCDD at RM 8.3 (g)[c]	50	6.8 to 9.0	6.3 to 8.2	6.1 to 8.5	8.0 to 9.1
Concentration of 2,3,7,8-TCDD on depositing fine sediment (ng/kg)	110 to 117	24 to 29	23 to 28	22 to 28	27 to 32
Total water column load of total PCBs at RM 8.3 (kg)[c]	195	135 to 138	135 to 138	134 to 139	145 to 148
Concentration of total PCBs on depositing fine sediment (mg/kg)	0.54	0.43 to 0.45	0.43 to 0.45	0.43 to 0.45	0.45 to 0.46
Construction duration (years)	--	4.3	4.6	4.9	3.2
RELATIVE COMPARISON OF CERCLA CRITERIA[d]					
1. Overall Protection of Human Health and the Environment[e]	No	Yes	Yes	Yes	No
2. Compliance with ARARs	Yes	Yes	Yes	Yes	Yes
3. Long-Term Effectiveness and Permanence					
Source Control and Recovery Potential					
Cap Stability					
Monitoring, Maintenance, and Institutional Controls					
4. Reduction of Toxicity, Mobility, or Volume through Treatment					
5. Short-Term Effectiveness					
Time to Achieve RAOs					
Worker Risk and Community Impact					
Resuspension					
Downstream and upstream transport					
6. Implementability					
7. Cost ($M)	**0**	**420**	**441**	**468**	**321**
Incremental Cost Increase (Decrease) Relative to Alternative 2	--	*0%*	*5%*	*11%*	*-24%*

Notes:

2,3,7,8-TCDD = 2,3,7,8- tetrachlorodibenzo-*p*-dioxin
ac = acre
ARAR = applicable or relevant and appropriate requirement
cy = cubic yard
M = million
PCB = polychlorinated biphenyl
RAO = remedial action objective
SWAC = surface area-weighted average concentration

The relative ranking of Alternatives 2, 3, and 4 for the balancing criteria requested by EPA, as reflected by circles filled in 5 percent increments (a more filled circle represents a higher degree of relative performance), is based on the evaluation of the specific metrics (including submetrics as relevant) or the measures that are described in the text to assess alternative performance. Where multiple metrics, submetrics, and/or measures are used to assess performance, they are aggregated to a total ranking for each criterion. Where comparison to a benchmark is possible (e.g., mass removed on an alternative-specific basis compared to total mass inventory), relative performance reflects this comparison. Where a benchmark does not exist, relative performance is reflected as a completely filled circle for the highest performing alternative and then comparatively diminished performance for the other alternatives. In the absence of a benchmark, a completely filled circle for the highest performing alternative does not necessarily represent all factors that could diminish the performance of even that highest performing alternative, but this methodology is reasonable to demonstrate a comparative evaluation between Alternatives 2, 3, and 4.

[a] Does not achieve the metrics for the threshold criteria for the upper 9-mile interim remedy, and therefore visual comparison of performance for the balancing criteria is not included in this table.

[b] Attained SWACs are lower than the target SWACs for the remedial alternatives due to additional sediment removal to achieve RAO 2.

[c] Approximate mass over the 10-year post-IR projection period at RM 8.3.

[d] Gradational differences in relative rankings against the balancing criteria denote incremental differences in remedial performance.

[e] Metrics used for this criterion include ability to achieve RAOs and ability to progress toward overall protection of human health and the environment by accelerating the recovery of sediment and water column concentrations of chemicals of concern.

Table 2-1. Surface (0–0.5 ft) Sediment Statistics

River Mile Range	Percent Fines	2,3,7,8-TCDD Concentration (ng/kg)						Total PCB Concentration (mg/kg)					
		n	min	max	mean	median	st. dev.	n	min	max	mean	median	st. dev.
Below RM 8	0–20	20	16	6,940	539	65	1,620	20	0.049	9.2	0.84	0.36	5.1
	20–40	81	0.045	22,400	1,160	200	3,890	81	0.0095	28.5	1.8	0.84	4.0
	> 60	150	0.77	34,100	1,080	210	4,050	150	0.0044	21.3	1.8	0.96	3.3
RM 8 to 12	0–20	51	0.44	890	83.5	38	138	52	0.006	24.7	0.81	0.18	3.4
	20–40	63	0.42	17,100	1,530	282	3,450	63	0.0016	21.9	2.4	0.91	4.3
	> 60	67	29.2	51,100	5,150	1,070	9,100	67	0.07	33.9	6.3	2.2	7.9
RM 12 to 14.6	0–20	31	0.53	465	43	8.1	96	31	0.041	8.9	0.71	0.25	1.7
	20–40	14	1.3	1,550	234	90.3	398	14	0.28	7.4	1.0	0.52	1.9
	> 60	9	59.4	17,600	2,400	490	5,710	9	0.12	23	4.1	1.7	7.2
RM 14.6 to Dundee Dam	0–20	17	0.026	0.85	0.34	0.33	0.24	17	0.025	2.9	0.29	0.093	0.69
	20–40	0	--	--	--	--	--	0	--	--	--	--	--
	> 60	1	0.031	0.031	0.031	0.031	--	1	0.0076	0.0076	0.0076	0.0076	--

Notes:
River Miles in RI RM system, which differs from the USACE RM system (used in this IR FS) by about 0.2 to 0.3 miles.
-- = no data
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
max = maximum
min = minimum
n = number of samples
PCB = polychlorinated biphenyl
st. dev. = standard deviation

Table 2-2. Summary of Preliminary Human Health COCs and Associated Risk

		RME				CTE		
Receptor	Medium	Cancer Risk	Preliminary COCs	Total HI	Preliminary COCs	Cancer Risk	Total HI	Preliminary COCs
RM 0–17								
Angler [a]	Mixed fish diet	4E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Heptachlor Epoxide, 4,4'-DDD, 4,4'-DDE, *cis*-Chlordane, *gamma*-Chlordane, Hexachlorobenzene	193	**TCDD-TEQ**, **PCBs**, **Mercury**, 4,4'-DDE, Dieldrin, Heptachlor Epoxide *trans*-Nonachlor	≤1E-4	15	**TCDD-TEQ**, **PCBs**
	Crab	1E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Arsenic, 4,4'-DDE, Heptachlor Epoxide	50	**TCDD-TEQ**, **PCBs**	≤1E-4	8	**TCDD-TEQ**, PCBs
RM 6–9								
Angler [a]	Mixed fish diet	4E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Heptachlor Epoxide, 4,4'-DDD, 4,4'-DDE, *cis*-Chlordane, *gamma*-Chlordane, Hexachlorobenzene	193	**TCDD-TEQ**, **PCBs**, **Mercury**, 4,4'-DDE, Dieldrin, Heptachlor Epoxide *trans*-Nonachlor	≤1E-4	15	**TCDD-TEQ**, **PCBs**
	Crab	1E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Arsenic, 4,4'-DDE, Heptachlor Epoxide	50	**TCDD-TEQ**, **PCBs**	≤1E-4	8	**TCDD-TEQ**, PCBs
Swimmer (child)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	≤1	
Swimmer (adolescent)	Accessible sediment	≤1E-4		3	**TCDD-TEQ**	≤1E-4	≤1	
Wader (child)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	≤1	
Wader (adolescent)	Accessible sediment	≤1E-4		3	**TCDD-TEQ**	≤1E-4	≤1	
Worker (adult)	Accessible sediment	≤1E-4		2	**TCDD-TEQ**	≤1E-4	≤1	
RM 6–9, East Bank								
Angler [a]	Mixed fish diet	4E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Heptachlor Epoxide, 4,4'-DDD, 4,4'-DDE, *cis*-Chlordane, *gamma*-Chlordane, Hexachlorobenzene	193	**TCDD-TEQ**, **PCBs**, **Mercury**, 4,4'-DDE, Dieldrin, Heptachlor Epoxide *trans*-Nonachlor	≤1E-4	15	**TCDD-TEQ**, **PCBs**
	Crab	1E-03	**TCDD-TEQ**, **PCBs**, Dieldrin, Arsenic, 4,4'-DDE, Heptachlor Epoxide	50	**TCDD-TEQ**, **PCBs**	≤1E-4	8	**TCDD-TEQ**, PCBs
Swimmer (child)	Accessible sediment	≤1E-4		6	**TCDD-TEQ**	≤1E-4	2	**TCDD-TEQ**
Swimmer (adolescent)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	2	**TCDD-TEQ**
Wader (child)	Accessible sediment	≤1E-4		5	**TCDD-TEQ**	≤1E-4	2	**TCDD-TEQ**
Wader (adolescent)	Accessible sediment	≤1E-4		4	**TCDD-TEQ**	≤1E-4	≤1	
Worker (adult)	Accessible sediment	≤1E-4		3	**TCDD-TEQ**	≤1E-4	≤1	

Notes: COCs shown in bold exceed risk of 1E-04 and/or hazard index of 1.

COC = chemical of concern
CTE = central tendency exposure
HI = hazard index
PCB = polychlorinated biphenyl
RME = reasonable maximum exposure
TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ = toxicity equivalence

[a] Table presents the highest calculated risk/hazard for the angler age groups evaluated in the BHHRA (combined adult/child for cancer and young child for noncancer).

Table 2-3. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
Metals						
Arsenic	*tissue:* worm (2.2) blue crab (2.2)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Cadmium	*no unacceptable risk*	*diet:* mummichog (1.3) common carp (1.2) white perch (1.1) white sucker (1.2) American eel (0.70–1.2)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Chromium	*tissue:* worm (6.0) mussel (3.7)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (160)	*no unacceptable risk*
Copper	*surface water:* estuarine (0.14–2.7) freshwater (0.034–1.0) *tissue:* blue crab (2.1)	*surface water:* estuarine (0.14–2.7) freshwater (0.023–1.0) *tissue:* mummichog (2.1) other forage fish (2.7) white perch (9.3) American eel (1.7)	*diet:* spotted sandpiper (0.30–3.6) great blue heron (0.029–1.3)	*no unacceptable risk*	*sediment* (2.4) *surface water* (estuarine: 1.8)	*surface water:* estuarine (0.14–2.7) freshwater (0.023–1.0)
Lead	*tissue:* worm (0.16–2.5)	*no unacceptable risk*	*diet:* spotted sandpiper (0.20–10) belted kingfisher (0.015–1.1)	*no unacceptable risk*	*sediment* (2.3)	*no unacceptable risk*
Methylmercury/mercury	*tissue:* blue crab: (1.3–1.5)	*tissue:* white catfish (0.71–1.1); American eel (0.74–1.1); largemouth bass (1.5–2.6); smallmouth bass (0.63–1.1) *egg tissue:* mummichog (0.11–1.1) *diet*: mummichog (1.3) common carp (1.1) white perch (1.3) white catfish (1.1) American eel (1.1–1.3)	*diet:* great blue heron (0.031–1.6) belted kingfisher (0.13–1.6)	*no unacceptable risk*	*sediment* (9.7)	*no unacceptable risk*
Nickel	*tissue:* worm (12) mussel (6.0)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Selenium	*tissue:* worm (1.1) blue crab (1.5)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (1.8)	*no unacceptable risk*
Silver	*tissue:* blue crab (1.0)	*no unacceptable risk*	*not evaluated (no toxicity data available)*	*not evaluated (no toxicity data available)*	*no unacceptable risk*	*no unacceptable risk*

Table 2-3. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
Vanadium	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (14)	*no unacceptable risk*
Zinc	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*sediment* (3.1) *surface water*: estuarine (21)	*no unacceptable risk*
Organometals						
TBT	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*surface water:* estuarine (1.1) freshwater (50)	*no unacceptable risk*
PAHs						
HPAHs	*tissue:* worm (0.090–3.0)	*no unacceptable risk*	*diet*: spotted sandpiper (1.9–10)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
PCBs						
Total PCBs	*tissue:* worm (0.46–14.1) blue crab (0.67–21) mussel (0.046–1.4)	*tissue:* mummichog (0.16–1.1) other forage fish (0.14–1.0) common carp (1.4–9.8) white perch (0.66–4.7) channel catfish (0.45–3.2) brown bullhead (0.37–2.6) white catfish (0.89–6.4) white sucker (0.76–5.5) American eel (0.53–3.8) largemouth bass (2.1–15) northern pike (0.53–3.8) smallmouth bass (0.37–2.6) *egg tissue:* mummichog (2.2–18) *diet:* northern pike (1.3)	*diet:* spotted sandpiper (0.047–1.2) great blue heron (0.031–1.1) *egg tissue:* great blue heron (0.078–284) belted kingfisher (0.22–76)	*diet:* mink (0.94–3.1) river otter (2.6–3.7)	*no unacceptable risk*	*no unacceptable risk*
PCB TEQ	*no unacceptable risk*	*tissue:* common carp (0.037–2.4) white perch (0.018–1.2) channel catfish (0.015–1.0) white catfish (0.029–1.9) white sucker (0.027–1.8) largemouth bass (0.14–9.4) northern pike (0.019-1.3) *diet:* white perch (1.0) American eel (0.95–1.8) largemouth bass (1.6) smallmouth bass (1.5) northern pike (2.1)	*diet:* spotted sandpiper (0.073–3.9) great blue heron (0.030–1.6) belted kingfisher (0.10–1.5) *egg tissue:* great blue heron (0.56–36) belted kingfisher (0.46–12)	*diet:* mink (0.12–1.1) river otter (0.31–1.4)	*not evaluated*	*not evaluated*

Table 2-3. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
PCDD/PCDFs						
2,3,7,8-TCDD	*surface water:* estuarine (0.0028–4.3) *tissue:* worm (0.013–29) blue crab (0.019–44) mussel (0.00073–1.7)	*tissue:* mummichog (0.41–27) other forage fish (0.38–26) common carp (5.1–340) white perch (1.6–110) channel catfish (0.80–53) brown bullhead (1.3–83) white catfish (1.8–120) white sucker (1.1–72) American eel (0.19–13) largemouth bass (1.5–100) northern pike (0.79–53) smallmouth bass (0.63–42)	*not evaluated*	*not evaluated*	*no unacceptable risk*	*no unacceptable risk*
PCDD/PCDF TEQ	*tissue:* worm (0.013–29) blue crab (0.021–48) mussel (0.00077–1.8)	*tissue:* mummichog (0.43–28) other forage fish (0.41–27) common carp (5.2–340) white perch (1.7–110) channel catfish (0.83–56) brown bullhead (1.3–89) white catfish (1.8–120) white sucker (1.1–72) American eel (0.20–13) largemouth bass (1.5–100) northern pike (0.83–56) smallmouth bass (0.63–42) *diet* : mummichog (200) common carp (200) white perch (170) channel catfish (190) white catfish (160) white sucker (190) American eel (180–190) largemouth bass (150) smallmouth bass (140) northern pike (200)	*diet:* spotted sandpiper (0.014–21) great blue heron (0.020–1.9) belted kingfisher (0.090–1.9) *egg tissue:* great blue heron (0.42–37) belted kingfisher (0.38–14)	*diet:* mink: (0.79–8.7) river otter (1.8–10)	*not evaluated*	*not evaluated*

Table 2-3. Summary of Preliminary Ecological COCs and Associated Hazard Quotients/Exceedance Factors

	Risk Range Results (Range of LOAEL HQs/EFs)[a]					
Preliminary COC	Benthic Invertebrates	Fish	Bird	Mammal	Aquatic Plants	Zooplankton
Total TEQ	*tissue:* worm (0.013–30) blue crab (0.021–48) mussel (0.00077–1.8)	*tissue:* mummichog: (0.43–28) other forage fish (0.41–27) common carp (5.2–340) white perch (1.7–110) channel catfish (0.83–56) brown bullhead (1.3–89) white catfish (1.9–130) white sucker (1.1–72) American eel (0.21–14) largemouth bass (1.5–100) northern pike (0.92–61) smallmouth bass (0.68–46) *diet:* mummichog (210) common carp (200) white perch (170) channel catfish (190) white catfish (160) white sucker (190) American eel (190–200) largemouth bass (150) smallmouth bass (140) northern pike (200)	*diet:* spotted sandpiper (0.089–25) great blue heron (0.044–3.5) belted kingfisher (0.18–3.1) *egg tissue:* great blue heron (1.0–74) belted kingfisher (0.85–23)	*diet:* mink (1.0–9.9) river otter (2.4–12)	*not evaluated*	*not evaluated*
Pesticides						
Total DDx	*tissue:* worm (0.12–1.6) blue crab (0.52–6.8)	*tissue* : common carp (1.3–1.7)	*diet:* spotted sandpiper (0.018–1.4) great blue heron (0.020–2.4) belted kingfisher (0.066–1.8) *egg tissue:* great blue heron (0.14–18) belted kingfisher (0.37–4.6)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Dieldrin	*no unacceptable risk*	*tissue:* common carp (0.28–1.4) channel catfish (0.24–1.2) American eel (0.27–1.4) largemouth bass (0.20–1.0) northern pike (0.22–1.1)	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*	*no unacceptable risk*
Other						
Cyanide	*surface water:* estuarine (1.3–4.1) freshwater (0.23–1.0)	*surface water:* estuarine (1.6–5.3)	*not evaluated*	*not evaluated*	*surface water:* estuarine (2.0)	*surface water:* estuarine (1.6–5.3)

Notes:

COC = chemical of concern
COPEC = chemical of potential ecological concern
EF = exceedance factor
DDx = DDT and metabolites
HPAH = high molecular weight polycyclic aromatic hydrocarbon
HQ = hazard quotient
LOAEL = lowest-observed-adverse-effect level
LOE = line of evidence
PCB = polychlorinated biphenyl
PCDD/PCDF = polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran
TBT = tributyltin
TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEQ = toxicity equivalence
TRV = toxicity reference value

[a] Preliminary COCs are identified as those COPECs with HQs ≥ 1.0 based on any LOE and effect-level concentration (i.e., HQ ≥ 1.0 based on a range of LOAELs for tissue and diet LOEs, HQ ≥ 1.0 based on acute or chronic surface water TRVs; HQ ≥ 1.0 based on plant-specific sediment TRVs).

Table 4-1. Potential Action-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
Clean Water Act, 33 U.S.C.1251 et seq.			
Water Quality Certification	Section 401; 40 CFR 121.2	A Water Quality Certification (WQC) specifies the requirements so that the proposed activity will comply with applicable water quality standards. Examples of activities requiring substantial conformance with a WQC include: • Discharge of dredged material dewatering effluent • Placement of fill in waters of the United States • Temporary discharges of decant waters from dredge material disposal sites or from barges and vessels.	ARAR. New Jersey has delegated authority. Section 401 of the CWA is implemented through compliance with the New Jersey Waterfront Development Law (N.J.S.A. 12:5-3), Coastal Zone Management Rules (N.J.A.C. 7:7). Anticipated substantive requirements, which would likely include implementation of BMPs and monitoring to meet water quality criteria during barge and dredge movement, anchoring, and operations.
National Pollutant Discharge Elimination System for Point Source Discharges	Section 402; 40 CFR Part 122	Establishes specific discharge limits for direct and indirect discharges (including stormwater) to surface water. Also establishes monitoring and reporting requirements.	ARAR. Applies to alternatives that include discharge to surface water.
Dredge and Fill Requirements	Section 404; 33 CFR Parts 320-323, 40 CFR 230	Regulates activities in waters of the U.S. including discharge of dredged materials, placement of fill materials, and reconstruction of mudflats. Section 404(b)(1) guidelines provide the substantive environmental criteria to be used in evaluating impacts on the aquatic ecosystem and provide for compensatory mitigation when there will be unavoidable impacts to waters of the United States.	ARAR. Substantive portions include implementation of BMPs and monitoring to meet water quality criteria during dredging, capping, barge and dredge movement, anchoring, and other in-water operations.
Pollution Prevention Regulations for Vessels	33 CFR Part 155, Subpart 1030	Intended to prevent pollution of waters by vessels, due to intentional or accidental discharges.	ARAR. Vessels are required to have spill plans and emergency spill equipment. Any fuel transfer over water necessary to run equipment on the barge would need to comply with U.S. Coast Guard regulatory requirements.
New Jersey Water Pollution Control Act, N.J.S.A. 58-10A-1 et seq. and Water Quality Planning Act, N.J.S.A. 58-11A-1 et seq.			
Pollutant Discharge Elimination System	N.J.A.C. 7:14A; N.J.A.C. 7:15	Establishes the designated uses and antidegradation categories of New Jersey's surface waters, classifies surface waters based on those uses (i.e., stream classifications), and specifies the water quality criteria and other policies and provisions necessary to attain those designated uses. Establishes discharge standards and approval process for direct and indirect discharges to protect water quality. Includes discharge standards specific to site remediation projects. Includes rules for implementing and operating project-related treatment works facility and ensures consistency with state wastewater management plans.	ARAR for alternatives that include discharge to surface water from publicly owned treatment works or project-related treatment works facility.
Stormwater Management	N.J.A.C.7:8	Design and performance standards for stormwater management during upland construction and operation of an upland facility.	ARAR for alternatives that include total land disturbance greater than 1 acre and includes preparing a stormwater pollution prevention plan and implementing BMPs to prevent discharge of pollutants. Also applicable to upland dredge material processing/treatment facility.
New Jersey Noise Control Act of 1971, N.J.S.A. 13:1G-1 et seq.			
Noise Control	N.J.A.C 7:20	Regulates noise levels for certain types of activities and facilities such as commercial, industrial, community service, and public service facilities.	ARAR for establishing allowable noise levels. A noise monitoring program will be designed as part of the Community Health and Safety Plan.

Table 4-1. Potential Action-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
Toxic Substances Control Act of 1976 (TSCA), 15 U.S.C. 2601 et seq.			
Management of PCB wastes	40 CFR Part 761	Regulates PCBs and other toxic substances from manufacture to disposal. Subpart D regulates storage and disposal of PCB waste. Establishes requirements for handling, storage, and disposal of PCB-containing materials, including PCB remediation wastes, and sets performance standards for disposal technologies for materials/wastes with concentrations in excess of 50 mg/kg. Establishes decontamination standards for PCB-contaminated debris. Prohibits the use of dilution to avoid TSCA requirements.	ARAR. Potentially applicable to environmental media containing PCBs at concentrations exceeding 50 mg/kg, which may be considered bulk PCB remediation waste.
Resource Conservation and Recovery Act (RCRA), 42 U.S.C. 6921 et seq.			
Management of Non-Hazardous Solid Waste Program (Subtitle D)	40 CFR 239-299 40 CFR 243, 40 CFR 256	Establishes requirements for generators, transporters, and facilities that manage non-hazardous solid waste.	ARAR for solid waste generated as part of the remediation project. The CERCLA Off-Site Rule (40 CFR 300.440) applies to any CERCLA response action involving the off-site transfer of any hazardous substance, pollutant, or contaminant (CERCLA wastes). The Off-Site Rule requires CERCLA wastes to be placed only in a facility operating in compliance with RCRA or other applicable federal or state requirements. These facilities include, but are not limited to, treatment, storage, and disposal facilities that are regulated under RCRA, TSCA, or any other applicable federal or state environmental law.
Management of Hazardous Waste (Subtitle C)	40 CFR 260-265, 40 CFR 268	Establishes requirements for generators, transporters, and facilities that manage hazardous solid waste. Provides for evaluation and control of materials that contain a listed waste, or that display a hazardous waste characteristic based on the toxicity characteristic leaching procedure (TCLP) test. Regulates storage, treatment, and disposal of listed or characteristic waste unless an exemption applies. Also establishes treatment standards (land disposal restrictions) for hazardous waste prior to disposal.	ARAR. Contaminated sediments that exhibit characteristics of hazardous waste (e.g., the characteristic of toxicity, based on testing according to the TCLP test) will be managed as hazardous waste. Prior to disposal as a hazardous waste, dredged material may require treatment. Requirements of the Off-Site Rule (see above) are also applicable for offsite transfer of hazardous wastes designated in accordance with RCRA Subtitle C.
Solid Waste Management Act, N.J.S.A. 13:1E-1 et seq.			
Management of Solid Waste	N.J.A.C. 7:26-2.1 Solid Waste	Establishes requirements for generators, transporters, and facilities that manage non-hazardous solid waste.	ARAR for solid waste generated as part of the remedial action. In New Jersey, dredged material is typically excluded from the definition of solid waste.
Management of Hazardous Waste	N.J.A.C. 7:26-G-1 et seq. Hazardous Waste Facilities	Establishes requirements for generators, transporters, and facilities that manage hazardous waste, and for thermal destruction facilities.	ARAR. Relevant and appropriate to sediment that is managed as hazardous waste generated as part of the remedial action.
Brownfield and Contaminated Site Remediation Act, N.J.S.A 58:10.3-1 et seq.			
Technical Requirements for Site Investigation and Remediation	N.J.A.C. 7:26 D, 7:26 E	Establishes minimum regulatory requirements for investigation and remediation of contaminated sites being addressed under New Jersey authorities and oversight.	ARAR. Substantive requirements for remedial action potentially relevant and appropriate for some aspects of remedial alternatives. TBC: NJDEP's "Technical Guidance on the Capping of Sites Undergoing Remediation," published pursuant to these requirements, provides general technical considerations, describes cap types and applications, and outlines monitoring considerations for the design and implementation of sediment caps for remediation of contaminated sediments.

Table 4-1. Potential Action-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
Hazardous Materials Transportation Act, 49 U.S.C. §1801-1819			
Hazardous Materials Transportation	49 CFR 171-177	Regulates the transportation of hazardous materials including procedures for packaging, labeling, manifesting, and transporting hazardous materials to a licensed offsite disposal facility.	ARAR for hazardous materials generated by the remedial action and shipped off-site for disposal.
Management and Regulation of Dredging Activities and Dredged Material Disposal in New Jersey's Tidal Water, December 1997			
Dredged Material Management	NJDEP Technical Manual	The manual provides guidance and criteria for the required sampling, testing, and permitting of proposed dredging projects and various dredged material management/disposal/use alternatives.	TBC. Use of BMPs and other techniques to reduce creation and dispersal of sediments and minimize adverse effects.
Clean Air Act, 42 U.S.C. § 7401 et seq.			
Air Emissions	40 CFR Parts 50-97	Provides emissions standards for specific contaminants and for categories of operating equipment.	ARAR potentially applicable if air emissions are generated from remedial actions.
Air Pollution Control Act, N.J.S.A. §26:2C et seq.			
Air Emissions	N.J.A.C. 7:27	Regulates sources/operations that emit contaminants from a variety of sources; controls and prohibits air pollution, particle emissions, and toxic volatile organic compound emissions including odors and dusts.	ARAR potentially applicable. Prohibits emissions in such quantities and duration as are, or tend to be, injurious to human health or welfare, animal or plant life or property, or would unreasonably interfere with the enjoyment of life or property.

Notes:
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
CFR = Code of Federal Regulations
CWA = Clean Water Act
N.J.A.C. = New Jersey Administrative Code
NJDEP = New Jersey Department of Environmental Protection
N.J.S.A. = New Jersey Statutes Annotated
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TBC = to be considered
TSCA = Toxic Substances Control Act
U.S.C. = United States Code

Table 4-2. Potential Location-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
Fish & Wildlife Coordination Act, 16 U.S.C. 661			
Protection of Wildlife	40 CFR 2 6:302(g)	Requires consideration of the effects of a proposed action on wetlands and areas affecting streams (including floodplains), as well as other protected habitats. Federal agencies must consult with USFWS prior to authorizing any modification of any stream or other water body, and requires adequate consideration to protect fish and wildlife resources and their habitats. Wildlife and wildlife resources include birds, fish, mammals, and all other classes of wild animals and all types of aquatic and land vegetation upon which wildlife is dependent.	ARAR. The Passaic River is a migratory pathway, nursery, and forage area for anadromous fish. NOAA will be consulted to determine if conservation measures are appropriate for the riverbed where dredging activities are occurring.
Migratory Bird Treaty Act, 16 U.S.C. 703-712			
Protection of Native and Migratory Birds	50 CFR 10	Requires that federal agencies consult with USFWS during remedial design and remedial construction to ensure that the cleanup of the site does not unnecessarily impact migratory birds. Protects native birds and migratory birds, as listed in 50 CFR 10.13, their nests, and eggs from unregulated "take," which can include disturbing active nests. Managed by USFWS.	ARAR. Bird activity has been observed along the LPR. Active bird nests cannot be removed without approval.
Endangered Species Act, Section 7, 16 U.S.C. 1531			
Protection of Threatened and Endangered Species	50 CFR Part 17 50 CFR Part 402	The Endangered Species Act provides broad protection for species of fish, wildlife, and plants that are listed as threatened or endangered in the U.S. or elsewhere. Applicable if any action may have an impact on an endangered species.	ARAR potentially applicable. The NJDEP Division of Fish and Wildlife Service will be consulted. Threatened, endangered, and of concern species have been identified along the LPR.
The Endangered and Non Game Species Conservation Act, N.J.S.A. 23:2A-1 to 23:2A-1:15			
Protection of Endangered, Threatened, or of Special Concern Species	Title 23 Fish and Game Wild Birds and Animals	Restricts activities where endangered, threatened, or of special concern species may be present	ARAR potentially applicable. The NJDEP Division of Fish and Wildlife Service will be consulted. Threatened, endangered, and of concern species have been identified along the LPR.
National Historic Preservation Act, 16 U.S.C. 470			
Historic Resources	36 CFR 800	Requires federal agencies to take into account the effect of any federally assisted undertaking or licensing on any district, site, building, structure, or object that is included in or is eligible for inclusion in the National Register of Historic Places. If the undertaking results in adverse effects, the agency must consult with the New Jersey Historic Preservation Office and other parties to develop ways to avoid, reduce, minimize, or mitigate any adverse impacts to those identified properties.	ARAR. A cultural survey will be conducted during the remedial design that will comply with the National Historic Preservation Act and aid in consultations with New Jersey Historic Preservation Office.

Table 4-2. Potential Location-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
New Jersey Register of Historic Places, N.J.S.A. 13:1B-15.128 et seq.			
Historic Resources	N.J.A.C. 7:4	Requires that actions by state, county, or local governments, which may impact a property listed in the New Jersey Register of Historic Places, be reviewed and authorized through the Historic Preservation Office.	ARAR potentially applicable. If federally assisted undertaking on any district, site, building, structure or object included in, or eligible for inclusion in, the National Register of Historic Places results in adverse effects, the agency must consult with the New Jersey Historic Preservation Office and other parties to develop ways to avoid, reduce, minimize, or mitigate any adverse impacts to those identified properties. A cultural resource survey (Phase I and II) will be conducted during the remedial design that will comply with the National Historic Preservation Act and aid in consultations with the New Jersey Historic Preservation Office.
Coastal Zone Management Act, 16 U.S.C. §§ 1451 et seq., §307 Coordination and Cooperation			
Coastal Resources	15 CFR Part 930	Requires that any federal agency undertaking a project in the coastal zone of a state shall ensure that the project is, to the maximum extent practicable, consistent with the enforceable policies of approved state management plans.	ARAR. Work will occur in areas that require substantive conformance with New Jersey Waterfront Development Law and New Jersey Coastal Zone Management Program and rules.
Section 10 Rivers and Harbors Act of 1899, 33 U.S.C. §403			
Wetlands; Navigable Waters	33 CFR 320-330	Regulates activities such as dredging and filling, and other construction in navigable waters of the U.S. Congressional approval required for any obstruction of the navigable capacity of the waters of the United States. Placement of pilings, or discharge of dredged material where the flow or circulation of waters of the United States may be impaired or the reach of such waters reduced must comply with Section 10.	ARAR for reaches of the river where dredging or capping will occur within navigable waters, as defined in 33 CFR 329. While permits are not required for onsite work, substantive requirements can be found in the General Permit and Regional Conditions.
New Jersey Waterfront Development Law (N.J.S.A. 12:5-3)			
Waterfront Development	Coastal Permit Program N.J.A.C. 7:7	Regulates any waterfront development, including sediment removal and fill, at or below mean high water and up to 500 ft from mean high water in the coastal zone and tidal waters of the state. Implemented through the Coastal Zone Management Program (N.J.A.C. 7:7), which provides rules and standards for use and development of resources in New Jersey's coastal zone.	ARAR. Dredging and filling projects require substantive conformance with Coastal Zone Management Program and rules. While permits are not required for onsite work, for alternatives that include an onsite sediment processing facility, an Acceptable Use Determination Permit-equivalent may be sought, to establish substantive requirements. Substantive requirements and BMPs include measures to minimize scouring and resuspension of sediment during dredging and placement of cap materials, slope management, and monitoring upstream and downstream.
Coastal Zone Management Rules/Standards	Coastal Zone Management N.J.A.C. 7:7	Provides standards for use and development of resources in New Jersey's coastal zone including those performed in accordance with the Waterfront Development Law. The rules are used in the review of water quality certificates subject to Section 401 of the Federal Clean Water Act, and federal consistency determinations under Section 307 of the Federal Coastal Zone Management Act, 16 U.S.C. § 1456. The rules also provide a basis for riparian grants, leases, and licenses.	ARAR. The Coastal Zone Management rules are considered in developing substantive requirements; Waterfront Development Permit/ Water Quality Certificate Permit Equivalents may be sought to establish compliance with substantive requirements.
Tidelands Act (Riparian Lands Leases, Grants, and Conveyances [N.J.S.A. 12:3-1 et seq.])			
Riparian lands owned by the State of New Jersey		Requires a tidelands lease, grant, or conveyance for the use of state-owned riparian lands, including sediment removal from rivers. The State of New Jersey owns riparian lands flowed by the mean high tide of a natural waterway, except for those lands in which it has already conveyed its interest in the form of a riparian grant.	ARAR. Sediment removal and backfill activities will require a tidelands lease. The application for the Tidelands Lease will be included in a Waterfront Development Permit-equivalent package. Substantive requirements include that development plans must be prepared by a professional engineer, and must depict the limits of the tidelands instrument, and notice to upland property owners.

Table 4-2. Potential Location-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
Protection of Wetlands, Executive Order 11990/Statement of Procedures on Wetlands Protection			
Wetlands	40 CFR Part 6, EPA policy and guidance for E.O. 11990 40 CFR Part 6, Appendix A	Requires that activities avoid, to the extent possible, long-term and short-term adverse effects associated with the modification or destruction of wetlands. Federal agencies are required to avoid direct or indirect support of new construction in wetlands where there are practical alternatives; harm to wetlands must be minimized when there is no practical alternative available.	TBC for alternatives involving remedial actions (including construction) in wetlands.
Wetland Act of 1970 (N.J.S.A. 13:9A-1 et seq.) and Freshwater Wetlands Protection Act (N.J.S.A. 13:9B)			
Establishes wetland and freshwater wetland regulated activities	N.J.A.C. 7:7A-2	Regulates construction or other activities (including remedial action) that will have an impact on wetlands, including working and transporting across coastal zone to upland processing facility.	ARAR for work in regulated wetlands and transition areas unless otherwise approved by USACE or covered under a water quality certificate issued by NJDEP. Requires minimization of impacts in wetlands.
Magnuson-Stevens Fishery Conservation and Management Act, as amended and authorized by the Sustainable Fisheries Act			
Fisheries	50 CFR Part 600 Public Law 94-265	Establishes 10 national standards for fishery conservation and management and requires that other federal agencies consult with the National Marine Fisheries Service (NMFS) on actions that may adversely affect essential fish habitats, which are defined as “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.”	ARAR. The LPR has been designated as essential fish habitat (EFH) for various fish species. Although measures recommended by NMFS to protect EFH are advisory, not prescriptive, EPA is required to consult with NMFS, and respond in writing to NMFS recommendations on actions or proposed actions that may adversely affect EFH. Consideration by NJDEP of actions that would create impediments to fish migration habitat impacts or that would lower water quality so as to interfere with fish movement patterns is also required under the New Jersey Coastal Zone Management standards. For the Phase 1 removal action on the LPR, EPA accepted the NMFS recommendation of a fish migration window precluding dredging from March 1 through June 30. It is anticipated that similar restrictions would be adopted for other remedial actions on the LPR. The dates of the fish window(s) precluding actions (e.g., dredging) will be set prior to scheduling those actions.
Floodplain Management: Executive Order 11988, Statement of Procedures on Floodplain Management			
Protect Floodplains	40 CFR Part 6, EPA policy and guidance for E.O. 11988 40 CFR Part 6, Appendix A	Requires evaluation of the potential effects of actions that may be taken in a floodplain and to avoid, to the extent possible, long-term and short-term adverse effects associated with the occupancy and modification of floodplains, and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative.	TBC for work that occurs in floodplain.
Flood Hazard Area Control Act, N.J.S.A. 58: 16A-50 et seq.			
Protect Floodplains	N.J.A.C. 7:13	Regulates activities (including remedial action) within flood hazard areas that will impact stream carrying capacity or flow velocity to avoid increasing impacts of flood waters, to minimize degradation of water quality, protect wildlife and fisheries, and protect and enhance public health and welfare. Consistent with N.J.A.C 7:13-10 and 7:13-11, it is not expected that the elevation of the river bottom or the mudflats would be increased above current conditions.	ARAR potentially applicable for work that occurs in flood hazard areas.

Table 4-2. Potential Location-Specific ARARs

Act/Authority	Citation	Brief Description	Applicability and Anticipated Requirements
Soil Erosion and Sediment Control Act, N.J.S.A. 4:24-39			
Prevent erosion and provide sediment control	N.J.A.C. 2:90	Regulates construction that will potentially result in erosion of soils and sediment, such as at an upland processing facility, and requires preparation of stormwater pollution prevention plan, designation of construction waste collection site, and site plan for construction related erosion. Applicable to land disturbance activities involving greater than 5,000 sq. ft.	ARAR potentially applicable for work that potentially results in erosion of soils.

Notes:
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CFR = Code of Federal Regulations
EFH = essential fish habitat
EPA = U.S. Environmental Protection Agency
ESA = Endangered Species Act
LPR = Lower Passaic River
NJDEP = New Jersey Department of Environmental Protection
NMFS = National Marine Fisheries Service
NOAA = National Oceanic and Atmospheric Administration
TBC = to be considered
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service

Table 5-1. Summary of Technology Screening

GRA	Technology Type	Process Option	Effectiveness	Implementability	Cost	Retained or Eliminated
No action	None	None	Would not address risks in the short term.	Easily implemented.	Low	Retained per NCP requirement
Institutional controls	Government controls, proprietary controls, informational devices	Commercial fishing bans, establishment of RNA, land use restrictions, deed notices, fish consumption advisories, signage	Potentially effective method to help reduce potential exposures to human health and the environment as a component of alternatives that include active measures.	Easily implementable, but requires monitoring to verify performance and ensure effectiveness.	Low	Retained[a]
Natural recovery	Monitored natural recovery (MNR)	Physical, biological, chemical monitoring	Effective for LPR COCs in areas with favorable conditions for recovery (e.g., low-scour potential, net depositional). Effective option for management of residual contamination outside of active remedial zones.	Easily implementable, demonstrated technology with broad application at similar sediment sites; Requires development of well-defined goals, performance metrics, and baseline conditions. Assumed to have considerable overlap with monitoring requirements.	Low	Retained[a]
	Enhanced natural recovery (ENR)	Thin-layer placement/residuals management cover	Effective option for management of dredge residuals (residuals management cover) and in access-constrained settings (e.g., under piers, near critical subsurface or shoreline structures). Requires favorable conditions for recovery (e.g., low-energy, low-scour potential, net depositional, biologically active).	Easily implementable, demonstrated technology; utilizes readily available equipment and materials; requires development of well-defined goals and performance metrics. Assumed to have considerable overlap with monitoring requirements.	Low to moderate	Retained for further evaluation[b]
In situ sediment treatment	Chemical	Activated carbon, organoclay, other amendments	Potentially effective option to address surface contamination in access-constrained areas (e.g., under piers/bridges, near bulkheads, utility crossings) and/or to reduce required cap thickness. Requires favorable conditions for recovery (e.g., low-energy, low-scour potential, net depositional, biologically active). May be used in conjunction with ENR strategies to improve effectiveness.	Emerging technology with increasing use and demonstrated success at similar sites across the U.S., utilizes readily available equipment and materials; selection of reactive materials may require bench or pilot scale studies; may require armoring in scour areas.	Low to moderate	Retained for further evaluation[b]
Ex situ sediment treatment	Physical	Soil/sediment washing	Effectiveness uncertain based on LPR pilot studies. Consistent performance has not been demonstrated. Ability to achieve beneficial use threshold criteria or land disposal restrictions is uncertain. Availability of economically viable use options is uncertain.	Emerging technology; equipment is commercially available, but no full scale application at similar sites; further testing would be required to demonstrate that technology could achieve cleanup criteria required for beneficial use.	Moderate to high	Retained for further evaluation[b]
	Chemical	Stabilization	Effective option for improving sediment handling and transport characteristics.	Implementable, demonstrated technology; utilizes readily available equipment and materials; Portland cement and other additives have been successfully added to dredged material at many other sites, including LPR. Commonly used to absorb excess water and prepare material for disposal.	Low to moderate	Retained[a]

Table 5-1. Summary of Technology Screening

GRA	Technology Type	Process Option	Effectiveness	Implementability	Cost	Retained or Eliminated
	Thermal	Thermal desorption	Limited effectiveness for LPR sediments due to decreased efficiency with increasing soil moisture and fines content. Does not treat heavy metals. Treatment residues require further processing before disposal/use. Ability to identify economically viable use options is uncertain.	Demonstrated effectiveness at other sediment remediation sites. Vaporized organic contaminants that are captured and condensed need to be destroyed by another technology. The resulting water stream from the condensation process may require further treatment. Not likely to be applicable to highly organic, fine-grained sediments but is retained for further consideration.	Moderate to high	Retained for further evaluation[b]
		Thermal destruction	Potentially effective option to destroy organic contaminants in LPR sediment. Heavy metals in ash residue may require additional treatment. Prior LPR pilot studies experienced operational difficulties and identified need to verify effectiveness for full-scale application. Ability to identify economically viable use options is uncertain.	Technology available as mobile units that would need to be set up at a fixed location in close proximity to the contaminated sediments. Cement-Lock® technology demonstration projects partially destroyed organics and encapsulated metals in the product matrix. The Cement-Lock® product passes the TCLP test for priority pollutants. Uncertainty remains as to feasibility of full-scale operation.	High	Retained for further evaluation[b]
		Incineration	Potentially effective option to destroy organic contaminants in LPR sediments that may be identified as RCRA characteristic wastes requiring treatment to meet land disposal requirements. Incineration is not effective for removal of heavy metal contamination. This treatment process may increase the leachability of metals through oxidation. Additionally, it requires air pollution control systems for removal of metals that may volatilize (e.g., mercury).	Demonstrated effectiveness and is commercially available. Applicable to LPR dewatered sediments. Nearest existing, permitted facility is greater than 500 miles from site. High energy consumption.	High	Retained for further evaluation[b]
		Vitrification	Potentially effective technology; however, there are currently no full-scale operating facilities with sufficient capacity to accept large volumes of sediments and as such, construction of a new facility would be required. Small sediment volumes could potentially be treated at off-site commercial sites. Ability to identify economically viable use options is uncertain.	Potentially commercially available as represented by Minergy Corp. glass furnace technology; however, it has not been applied on similar site and scale.	Moderate to high	Retained for further evaluation[b]
Containment	Capping	Engineered cap	Effective option for isolation and containment of subsurface contamination using engineered layers of sand cover.	Easily implementable, demonstrated technology; utilizes readily available equipment and materials; conventional sand caps have been used extensively at similar sediment sites nationally, including the LPR.	Moderate	Retained[a]
		Armored cap	Effective option for physical isolation and containment of contaminants. Typically consists of sand cover and other structural elements (such as stone armor) to provide resistance to erosive forces.	Easily implementable, demonstrated technology; utilizes readily available equipment and materials; has been used extensively at similar sediment sites nationally, including the LPR.	Moderate	Retained[a]
		Composite Cap	Effective option for physical isolation and containment of contaminants through layering of sand and composite materials (e.g., geotextile, high-density polyethylene) to provide scour protection, physical separation, control ebullition, and filtering, and to reduce cap thickness.	Easily implementable, demonstrated technology; utilizes readily available equipment and materials; has been used extensively at similar sediment sites nationally.	Moderate	Retained for further evaluation[b]

Table 5-1. Summary of Technology Screening

GRA	Technology Type	Process Option	Effectiveness	Implementability	Cost	Retained or Eliminated
		Reactive cap	Potentially effective option to enhance cap performance and address (treat) potential dissolved and liquid phase contaminants, and if needed, to reduce cap thickness.	Emerging technology with increasing use and demonstrated success at similar sites across the U.S., including the LPR (RM 10.9 removal action). Utilizes readily available equipment and materials. Selection of reactive materials to increase sorptive capacity of cap may require bench- or pilot-scale studies.	Moderate	Retained for further evaluation[b]
Sediment removal	Dredging	Mechanical dredging (clamshell, hydraulic excavator)	Effective option for removal of LPR sediments. Technology has been effectively implemented for decades in the LPR for navigational dredging and more recently for environmental dredging projects.	Mechanical dredging is available and a demonstrated technology. Generally applicable to LPR in water site conditions. Well suited for higher density, low water solids, and more effective at handling debris. Environmental buckets suitable for softer materials with low debris; clamshell buckets suitable for harder, dense sediments. Precision dredges are specialized, but generally available. Technology has demonstrated success at other similar sites.	Moderate	Retained[a]
		Specialty dredging	Effective option for small scale removal (e.g., adjacent and under structures). Methods include diver-assisted and other small-scale hydraulic dredging methods (e.g., Mud Cat, Sed-Vac).	Specialty dredging methods are available and demonstrated technologies that are implementable for focused, small-scale removal.	Moderate to high	Retained for further evaluation[b]
		Hydraulic dredging	Limited effectiveness due to consolidated nature of LPR sediments and implementability constraints.	Hydraulic environmental dredging is available and a demonstrated technology. High levels of debris, sediment characteristics, and large-scale dewatering and water treatment requirements limit the applicability of this technology to the LPR.	Moderate	Retained for further evaluation[b]
	Dry excavation	Land-based excavator	Potentially effective option for removal of LPR sediments in intertidal shoreline areas. Excavation in-the-dry allows better visual control and verification of removal and backfill operations (during low-tide cycles). Less water generated. Access constraints may preclude use.	Equipment is readily available and has been demonstrated at many similar sites. Limited in application to nearshore shallow and/or intertidal areas that can be reached from shore or by specialty equipment designed to work on soft unconsolidated sediments.	Moderate	Retained[a]
Transport of sediment and capping materials	Mechanical transport	Barge transport, trucks and roll-off boxes, rail	Effective option for transport of LPR sediments. Barge transport has been effectively implemented in the LPR for navigational dredging and more recently for environmental dredging projects. Overland transport options are effective and proven technologies, implemented in the LPR and elsewhere.	Implementable. Site-specific constraint will affect production rates and equipment selection and availability.	Moderate	Retained[a]
	Hydraulic transport		Potentially effective option for transport of LPR sediments. Technology has been effectively implemented for small-scale removal efforts (i.e., Tierra Phase I Removal Action).	Demonstrated implementability. For the LPR, would be subject to challenges associated with siting potential processing facilities (e.g., pipeline length, and accommodation of vessel traffic).	Moderate to high	Retained for further evaluation[b]

Table 5-1. Summary of Technology Screening

GRA	Technology Type	Process Option	Effectiveness	Implementability	Cost	Retained or Eliminated
Disposal	Onsite disposal	Confined aquatic disposal (CAD)	Limited effectiveness for LPR sediments due to absence of available CAD facility and technical and administrative barriers to constructing a new CAD(s).	CADs have been historically constructed in Newark Bay to support navigational dredging, but there are currently no available CAD sites to accept LPR sediments. Challenges to construction of a new CAD facility include potential environmental impacts, regulatory and public concerns, and lengthy site characterization and permitting process. This option is not anticipated to receive state or community acceptance.	Moderate to high	Retained for further evaluation[b]
		Confined disposal facility (CDF)	Limited effectiveness for LPR sediments due to absence of available CDF site and technical and administrative barriers to constructing a new CDF facility.	There are currently no available CDF sites to accept LPR sediments. Construction of a new CDF would be difficult due to lack of available sites, environmental impacts, regulatory and public concerns, and lengthy site characterization and permitting process. This option is not anticipated to receive state or community acceptance.	Moderate to high	Retained for further evaluation[b]
	Offsite disposal	Subtitle D landfill	Potentially effective option for disposal of LPR sediments, dependent on waste characterization.	Readily available process option. Waste characterization testing would be required to verify implementability of this option. Sediments would require dewatering and possible stabilization prior to transport.	Moderate	Retained for further evaluation[b]
		Subtitle C landfill	Potentially effective option for disposal of LPR sediments.	Available and demonstrated on prior LPR removal actions. Applicable to LPR dewatered sediments.	High	Retained[a]
Beneficial Use	Beneficial use of dredged sediment	Sanitary landfill cover, construction fill, and mined lands restoration	Limited effectiveness for LPR sediments due to uncertainties in treatment processes of achieving threshold criteria for intended beneficial use. Ability to identify economically viable use options is uncertain.	Demonstrated applicable to navigation dredging projects. No specific beneficial upland use or market has been identified for Superfund material. Implementability is dependent on the requirements of the state where the material is destined for beneficial use.	Low to moderate	Retained for further evaluation[b]

Notes:
COC = chemical of concern
GRA = general response action
LPR = Lower Passaic River
NCP = National Oil and Hazardous Substances Pollution Contingency Plan (also known as the National Contingency Plan)
TCLP = toxicity characteristic leaching procedure
RCRA = Resource Conservation and Recovery Act
RNA = regulated navigation area
[a] Technologies "retained" are the representative process options presented in this feasibility study.
[b] Technologies "retained for further evaluation" may be considered during remedial design, but have not been included as elements of the alternatives presented in this feasibility study.

Table 7-1. Summary of Estimated Areas, Volumes, and Durations of the Alternatives

Alternative	Description	Area (ac)	Volume (cy)[a]	Construction Duration (years)[b]
1	No Action	--	--	--
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	90	363,000	4.3
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	96	387,000	4.6
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	104	419,000	4.9
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	62	250,000	3.2

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

ac = acre

cy = cubic yard

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

[a] Excavation depth assumed to be 2.5 ft, which includes a provision for a 0.5-ft overdredge allowance (Appendix A).

[b] Rate of removal is assumed to be between 476 cy/day and 813 cy/day; variation is based on dredging location and equipment. Construction duration estimates assume 24-hour workdays, six days per week (Appendix A).

Table 7-2. Summary of Estimated SWACs and RALs

Alternative	Parameter	Concentration 2,3,7,8-TCDD (ng/kg)	Concentration Total PCBs (mg/kg)
2	Target SWAC [a]	85	0.46
	Delineated SWAC [b]	80	0.29
	Surface RAL[c]	260	1
	Subsurface RAL[d]	520	2
3	Target SWAC [a]	75	0.46
	Delineated SWAC [b]	70	0.27
	Surface RAL[c]	205	1
	Subsurface RAL[d]	410	2
4	Target SWAC [a]	65	0.46
	Delineated SWAC [b]	60	0.24
	Surface RAL[c]	164	1
	Subsurface RAL[d]	328	2
5	Target SWAC [a]	125	0.46
	Delineated SWAC [b]	121	0.49
	Surface RAL[c]	346	--
	Subsurface RAL[d]	692	--

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

[a] Target SWACs were developed based on RAO 1 and establish the remedial footprints for each alternative.

[b] Delineated SWACs refer to the modeled post-construction surface sediment SWAC results of each remedial alternative.

[c] Surface RALs are applied between 0 and 6 in. below sediment surface.

[d] Subsurface RALs are applied between 0.5 to 1.5 ft below sediment surface.

Table 8-1. LPR Upper 9-Mile IR FS Evaluation Metrics

CERCLA Criterion	IR FS Evaluation Criterion	Metrics for Evaluation
Threshold		
1. Overall protection of human health and the environment	Ability to achieve RAOs	Does not/can meet criterion
	Ability to progress toward overall protection by promoting continued recovery of sediment and water column COC concentrations	Does not/can meet criterion
2. Compliance with ARARs	Ability to achieve ARARs	Does not/can meet criterion
	Need for ARAR waivers	Discussion of potential waivers (e.g., water quality criteria)
Balancing		
3. Long-term effectiveness and permanence	Source control/recovery potential	Degree of achievement supported by • Efficacy of RALs based on conceptual site model • Areas, masses, and volumes of source removal • Distribution of post-IR concentrations relative to pre-IR concentrations • Projections of: – Average sediment concentrations and recovery half-life expressed as ranges and compared among alternatives and with MNR [Table 8-2, Model Projection Metric #1, #2] – Average water column particulate concentrations expressed as ranges and compared among alternatives and with MNR [Table 8-2, Model Projection Metric #4] – Average and cumulative contaminant loads expressed as ranges and compared among alternatives and with MNR [Table 8-2, Model Projection Metric #5, #6] – Average net and gross sediment contaminant flux expressed as ranges and compared among alternatives and with MNR [Table 8-2, Model Projection Metric #9] – Average contaminant concentrations on depositing fines expressed as ranges and compared among alternatives and with MNR [Table 8-2, Model Projection Metric #10]
	Cap stability	Cap modeling

Table 8-1. LPR Upper 9-Mile IR FS Evaluation Metrics

CERCLA Criterion	IR FS Evaluation Criterion	Metrics for Evaluation
	Monitoring, maintenance, and institutional controls	Degree of achievement, supported by discussion of anticipated extent of requirements as a function of remedy size
4. Reduction of toxicity, mobility or volume through treatment	Source control, capping, amendments, disposal	Degree of achievement supported by removal volumes, masses, and cap areas
5. Short-term effectiveness	Time to achieve RAOs	Estimated construction duration; achievement or non-achievement of RAOs at completion of remedy implementation
	Worker risks, community impacts	Estimates based on durations, construction approaches, and volumes
	Resuspension	Projections of average water column particulate concentrations during construction expressed as ranges and compared among alternatives and to MNR [Table 8-2, Model Projection Metric #3]
	Downstream and upstream transport	Projections of average and cumulative contaminant fluxes at RM 0, RM 8.3, and RM 15 during construction expressed as ranges and compared among alternatives and with MNR [Table 8-2, Model Projection Metric #7, #8]
6. Implementability	Technical feasibility, BMPs, monitoring, construction challenges, availability of services and materials, future use, administrative matters	Discussion including technical feasibility of remediating in challenging areas (e.g., utility corridors), Waterways Conditions Assessment, lessons learned from RM 10.9 and Phase I removal actions, potential synergies with the lower 8.3-mile remedy
7. Cost	Undiscounted and present value cost estimates	Quantitative ranking supported by cost sensitivity
Modifying		
8. State acceptance	Considered by EPA during remedy selection and ROD preparation	
9. Community acceptance	Considered by EPA during remedy selection and ROD preparation	

Notes:
ARAR = applicable or relevant and appropriate requirement
BMP = best management practice
CERCLA = Comprehensive Environmental Response, Compensation and Liability Act
EPA = U.S. Environmental Protection Agency
FS = feasibility study
IR = interim remedy

LPR = Lower Passaic River
MNR = monitored natural recovery
RAL = remedial action level
RAO = remedial action objective
RM = river mile
ROD = record of decision

Table 8-2. Model Projection Metrics to Support IR FS Evaluation Metrics

Model Result	Metric to Compare Alternatives	Method of Comparing Ranges of Results among Alternatives	Cross Reference to Table 8-1
Average Surface Sediment COPC Concentration (SWAC) for RM 0–RM 8.3, RM 8.3–RM 15 and RM 0–RM 15	Recovery half-life during the post-IR period	Recovery half-life compared among active IR alternatives and MNR, and relative changes in half-lives for active IR alternatives compared to rate for MNR	1
	End of year averages during the post-IR period	End of year averages compared among active IR alternatives and MNR, and relative changes in end of year averages for active IR alternatives compared to MNR	2
Average Water Column COPC Concentration for RM 8.3–RM 15	Averages during the IR implementation period	Averages compared among active IR alternatives and MNR, and relative changes in averages for active IR alternatives compared to MNR	3
	End of year averages during the post-IR period and post-IR period average	End of year averages compared among active IR alternatives and MNR, and relative changes in end of year averages for active IR alternatives compared to MNR	4
COPC Load at RM 0, RM 8.3, and RM 15	Annual averages during the post-IR period	Averages compared among active IR alternatives and MNR, and relative changes in averages for active IR alternatives compared to MNR	5
	Cumulative loads during the post-IR period	Cumulative loads compared among active IR alternatives and MNR, and relative changes in cumulative fluxes for active IR alternatives compared to MNR	6
	Averages during IR implementation period	Averages compared among active IR alternatives and MNR, and relative changes in averages for active IR alternatives compared to MNR	7

Table 8-2. Model Projection Metrics to Support IR FS Evaluation Metrics

Model Result	Metric to Compare Alternatives	Method of Comparing Ranges of Results among Alternatives	Cross Reference to Table 8-1
	Cumulative loads during IR implementation period	Cumulative loads compared among active IR alternatives and MNR, and relative changes in cumulative loads for active IR alternatives compared to MNR	8
Average Net and Gross Sediment Contaminant Erosion Flux for RM 8.3–RM 15	End of year averages during the post-IR period and post-IR period average	Averages compared among active IR alternatives and MNR, and relative changes in averages for active IR alternatives compared to MNR	9
Average COC Concentration on Depositing Fine Sediment for RM 8.3–RM 15	End of year averages during the post-IR period and post-IR period average	Averages compared among active IR alternatives and MNR, and relative changes in averages for active IR alternatives compared to MNR	10

Notes:
COPC = chemical of potential concern
FS = feasibility study
IR = interim remedy
MNR = monitored natural recovery
SWAC = surface area-weighted average concentration

Table 8-3. Range of Remedial Footprint Areas, Dredge Volumes, and RALs for 100 Maps[a]

Alternative		Map Statistic	Remedial Footprint (ac)	Removal Volume (cy)[b]	Surface RAL (ng/kg)
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	CS 37	90	363,000	260
		Mean	88	355,000	250
		Range	74–106	298,000–428,000	183–352
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	CS 37	96	387,000	205
		Mean	95	383,000	198
		Range	79–115	319,000–464,000	144–275
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	CS 37	104	419,000	164
		Mean	102	411,000	158
		Range	87–122	351,000–492,000	115–212
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	CS 37	62	250,000	346
		Mean	61	246,000	345
		Range	44–75	177,000–303,000	256–470

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
ac = acre
CS 37 = conditional simulation 37
cy = cubic yard
PCB = polychlorinated biphenyl
RAL = remedial action level

[a] A statistical interpolation was applied to generate 100 equally probable maps. The values in this table show the ranges based on the footprints delineated for the 100 maps.
[b] Excavation depth is assumed to be 2.5 ft, which includes a provision for a 0.5-ft overdredge allowance (Appendix A).

Table 8-4. Summary of Cost Estimates

Alternative	Description	Direct Capital ($M) [a]	Indirect Capital ($M)	Total Capital ($M)	Annual OMM ($M/year) [a,b]	Periodic OMM ($M) [a]	Present Value ($M) [c]
1	No Action	0.0	0.0	0.0	0.0	0.0	0.0
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	335	113	448	0.9	50	420
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	357	116	472	0.9	50	441
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	385	119	504	0.9	51	468
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	233	100	333	0.9	47	321

Notes:

Estimates represent a feasibility level of accuracy (+50/-30%).

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

M = million

OMM = operation, maintenance, and monitoring

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

[a] Direct capital, annual OMM, and periodic costs include 25% contingency.

[b] Annual OMM costs are assumed to begin in Year 5 and extend for 30 years after construction is complete.

[c] Discount rate from EPA guide to developing and documenting cost estimates during the feasibility study (USEPA 2000a).

Table 8-5. Sensitivity Analysis of Cost Estimate Contingency and Discount Rates

Alternative	Description	Discount Rate	Cost ($M) 25% Contingency	Cost ($M) 35% Contingency
1	No Action	0.0%	0	0
		1.5%[a]	0	0
		7.0%[b]	0	0
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	0.0%	524	560
		1.5%	494	528
		7.0%	420	448
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	0.0%	549	587
		1.5%	518	553
		7.0%	441	470
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	0.0%	581	622
		1.5%	549	587
		7.0%	468	500
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	0.0%	406	433
		1.5%	381	406
		7.0%	321	341

Notes:

Base costs are discounted at 7.0%, with 25% contingency.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

M = million

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

[a] Discount rate from the U.S. Office of Management and Budget's Circular A-94 Guideline and Discount Rates for Benefit-Cost Analysis of Federal Programs real interest rates for a 30-year time period (OMB 2018)

[b] Discount rate from EPA guide to developing and documenting cost estimates during the feasibility study (USEPA 2000a)

Table 8-6. Range of Remedial Footprints with Varying 2,3,7,8-TCDD Subsurface RALs for 100 Maps[a]

Alternative	Description	Factor of 2,3,7,8-TCDD Surface RAL[b]	Area Added to Remedial Footprint with RAO 2 (ac)	Remedial Footprint (ac)
2	2,3,7,8-TCDD target SWAC = 85 ppt,	2x	3–7	74–106
	Total PCBs RAL = 1 ppm	1x	5–10	76–108
3	2,3,7,8-TCDD target SWAC = 75 ppt,	2x	3–7	79–115
	Total PCBs RAL = 1 ppm	1x	5–9	82–117
4	2,3,7,8-TCDD target SWAC = 65 ppt,	2x	3–6	87–122
	Total PCBs RAL = 1 ppm	1x	5–9	89–124
5	2,3,7,8-TCDD target SWAC = 125 ppt,	2x	1–4	44–75
	no Total PCBs RAL	1x	5–9	47–79

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
ac = acre
PCB = polychlorinated biphenyl
RAL = remedial action level
RAO = remedial action objective
SWAC = surface area-weighted average concentration
[a] A statistical interpolation was applied to generate 100 equally probable maps. The values in this table show the ranges based on the footprints delineated for the 100 maps.
[b] The subsurface RAL for total PCBs was held constant at twice the total PCBs surface RAL.

Table 8-7. Comparative Analysis of Remedial Alternatives

	Alternative 1 [a]	Alternative 2	Alternative 3	Alternative 4	Alternative 5 [a]
KEY METRICS SUMMARY					
Delineated 2,3,7,8-TCDD surficial SWAC achieved based on CS 37 map (ng/kg)[b]	--	80	70	60	121
Delineated total PCB surficial SWAC achieved based on CS 37 map (mg/kg)	--	0.29	0.27	0.24	0.49
Area of removal (ac)	--	90	96	104	62
Volume of removal (cy)	--	363,000	387,000	419,000	250,000
Mass of 2,3,7,8-TCDD removed from the surficial interval (0-0.5 ft) (g)	--	123	124	125	117
Mass of 2,3,7,8-TCDD removed from the dredge prism (0-2.5 ft) (g)	--	590	610	630	530
Mass of total PCBs removed from the surficial interval (0-0.5 ft) (kg)	--	161	163	167	135
Mass of total PCBs removed from the dredge prism (0-2.5 ft) (kg)	--	810	840	860	630
Total water column load of 2,3,7,8-TCDD at RM 8.3 (g)[c]	50	6.8 to 9.0	6.3 to 8.2	6.1 to 8.5	8.0 to 9.1
Concentration of 2,3,7,8-TCDD on depositing fine sediment (ng/kg)	110 to 117	24 to 29	23 to 28	22 to 28	27 to 32
Total water column load of total PCBs at RM 8.3 (kg)[c]	195	135 to 138	135 to 138	134 to 139	145 to 148
Concentration of total PCBs on depositing fine sediment (mg/kg)	0.54	0.43 to 0.45	0.43 to 0.45	0.43 to 0.45	0.45 to 0.46
Construction duration (years)	--	4.3	4.6	4.9	3.2
RELATIVE COMPARISON OF CERCLA CRITERIA[d]					
1. Overall Protection of Human Health and the Environment[e]	No	Yes	Yes	Yes	No
2. Compliance with ARARs	Yes	Yes	Yes	Yes	Yes
3. Long-Term Effectiveness and Permanence					
Source Control and Recovery Potential					
Cap Stability					
Monitoring, Maintenance, and Institutional Controls					
4. Reduction of Toxicity, Mobility, or Volume through Treatment					
5. Short-Term Effectiveness					
Time to Achieve RAOs					
Worker Risk and Community Impact					
Resuspension					
Downstream and upstream transport					
6. Implementability					
7. Cost ($M)	**0**	**420**	**441**	**468**	**321**
Incremental Cost Increase (Decrease) Relative to Alternative 2	--	*0%*	*5%*	*11%*	*-24%*

Notes:

2,3,7,8-TCDD = 2,3,7,8- tetrachlorodibenzo-*p*-dioxin
ac = acre
ARAR = applicable or relevant and appropriate requirement
cy = cubic yard
M = million
PCB = polychlorinated biphenyl
RAO = remedial action objective
SWAC = surface area-weighted average concentration

The relative ranking of Alternatives 2, 3, and 4 for the balancing criteria requested by EPA, as reflected by circles filled in 5 percent increments (a more filled circle represents a higher degree of relative performance), is based on the evaluation of the specific metrics (including submetrics as relevant) or the measures that are described in the text to assess alternative performance. Where multiple metrics, submetrics, and/or measures are used to assess performance, they are aggregated to a total ranking for each criterion. Where comparison to a benchmark is possible (e.g., mass removed on an alternative-specific basis compared to total mass inventory), relative performance reflects this comparison. Where a benchmark does not exist, relative performance is reflected as a completely filled circle for the highest performing alternative and then comparatively diminished performance for the other alternatives. In the absence of a benchmark, a completely filled circle for the highest performing alternative does not necessarily represent all factors that could diminish the performance of even that highest performing alternative, but this methodology is reasonable to demonstrate a comparative evaluation between Alternatives 2, 3, and 4.

[a] Does not achieve the metrics for the threshold criteria for the upper 9-mile interim remedy, and therefore visual comparison of performance for the balancing criteria is not included in this table.

[b] Attained SWACs are lower than the target SWACs for the remedial alternatives due to additional sediment removal to achieve RAO 2.

[c] Approximate mass over the 10-year post-IR projection period at RM 8.3.

[d] Gradational differences in relative rankings against the balancing criteria denote incremental differences in remedial performance.

[e] Metrics used for this criterion include ability to achieve RAOs and ability to progress toward overall protection of human health and the environment by accelerating the recovery of sediment and water column concentrations of chemicals of concern.

Table 8-8. Ranges of Model Projections for Model Metrics

	SWAC at Year 10 in RM 8.3-15 (ng/kg)		SWAC Half-Life in RM 8.3-15 over 10-Year Post-IR Period (years)		SWAC at Year 10 in RM 0-8.3 (ng/kg)		SWAC at Year 10 in RM 0-15 (ng/kg)		Average Water Column Concentration over 10-Year Post-IR Period (pg/L)		Total Water Column Load at RM 8.3 over 10-Year Post-IR Period (g)		Average Gross Erosional Flux over 10-Year Post-IR Period (g/yr)		Average Net Erosional Flux over 10-Year Post-IR Period (g/yr)		Average Concentration on Depositing Fine Sediment over 10-Year Post-IR Period (ng/kg)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
2,3,7,8-TCDD																		
Alternative 1	625	630	125	244	32	35	203	206	1.4	1.5	50	50	11.8	12.2	4.8	4.8	111	117
Alternative 2	52	80	8.1	18	12	16	24	34	0.31	0.37	6.8	9.0	2.0	2.5	0.48	0.67	24	29
Alternative 3	45	69	7.6	15	12	16	21	31	0.29	0.36	6.3	8.2	1.9	2.4	0.43	0.62	23	28
Alternative 4	39	60	7.1	13	12	15	19	28	0.29	0.37	6.1	8.5	1.8	2.4	0.41	0.64	23	28
Alternative 5	87	106	15	65	12	16	34	42	0.35	0.39	8.0	9.1	2.3	2.7	0.60	0.71	28	31

	SWAC at Year 10 in RM 8.3-15 (mg/kg)		SWAC Half-Life in RM 8.3-15 over 10-Year Post-IR Period (years)		SWAC at Year 10 in RM 0-8.3 (mg/kg)		SWAC at Year 10 in RM 0-15 (mg/kg)		Average Water Column Concentration over 10-Year Post-IR Period (ng/L)		Total Water Column Load at RM 8.3 over 10-Year Post-IR Period (kg)		Average Gross Erosional Flux over 10-Year Post-IR Period (kg/yr)		Average Net Erosional Flux over 10-Year Post-IR Period (kg/yr)		Average Concentration on Depositing Fine Sediment over 10-year Post-IR Period (mg/kg)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Total PCBs																		
Alternative 1	1.02	1.02	79	110	0.17	0.17	0.41	0.42	10.2	10.2	195	195	36	37	6.5	6.5	0.54	0.54
Alternative 2	0.23	0.31	18	46	0.14	0.15	0.17	0.20	8.4	8.5	135	138	25	26	0.92	1.4	0.43	0.45
Alternative 3	0.21	0.29	17	43	0.14	0.15	0.16	0.19	8.4	8.5	135	138	25	26	0.82	1.3	0.43	0.45
Alternative 4	0.19	0.27	18	43	0.14	0.15	0.16	0.18	8.4	8.6	134	139	25	27	0.81	1.3	0.43	0.45
Alternative 5	0.37	0.43	36	71	0.15	0.15	0.21	0.23	8.8	9.0	145	148	27	28	2.0	2.2	0.45	0.46

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
IR = interim remedy
PCB = polychlorinated biphenyl
RM = river mile
SWAC = surface area-weighted average concentration

Table 8-9. Overlap of Ranges of Model Projections for Model Metrics

	Range of Alternative 2	Range of Alternative 4	Range of Overlap	% Overlap (Range of Overlap/ Range of Alternative 4)
2,3,7,8-TCDD				
SWAC at Year 10 Post-IR in RM 8.3-15 (ng/kg)	28	21	7	35%
SWAC Half-Life in RM 8.3-15 over 10-year post-IR period (years)	9.5	6.2	5.2	84%
SWAC at Year 10 Post-IR in RM 0-8.3 (ng/kg)	4.1	3.9	3.6	91%
SWAC at Year 10 Post-IR in RM 0-15 (ng/kg)	10.9	8.9	4.7	53%
Average Water Column Concentration over 10-Year Post-IR Period (pg/L)	0.06	0.08	0.06	74%
Total Water Column Load at RM 8.3 over 10-Year Post-IR Period (g)	2.2	2.4	1.7	70%
Average Gross Erosional Flux over 10-Year Post-IR Period (g/yr)	0.5	0.5	0.3	64%
Average Net Erosional Flux over 10-Year Post-IR Period (g/yr)	0.19	0.23	0.16	70%
Average Concentration on Depositing Fine Sediment over 10-Year Post-IR Period (ng/kg)	4.7	5.1	3.2	62%
Total PCBs				
SWAC at Year 10 in RM 8.3-15 (mg/kg)	0.1	0.08	0.05	59%
SWAC Half-Life in RM 8.3-15 over 10-year post-IR period (years)	28	26	26	100%
SWAC at Year 10 Post-IR in RM 0-8.3 (mg/kg)	0.01	0.01	0.01	88%
SWAC at Year 10 Post-IR in RM 0-15 (mg/kg)	0.03	0.03	0.02	64%
Average Water Column Concentration over 10-Year Post-IR Period (ng/L)	0.09	0.21	0.16	76%
Total Water Column Load at RM 8.3 over 10-Year Post-IR Period (kg)	3.0	5.3	3.7	70%
Average Gross Erosional Flux over 10-year Post-IR Period (kg/yr)	1.1	1.9	1.6	83%
Average Net Erosional Flux over 10-Year Post-IR Period (kg/yr)	0.49	0.49	0.37	76%
Average Concentration on Depositing Fine Sediment over 10-Year Post-IR Period (mg/kg)	0.014	0.024	0.020	86%

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
IR = interim remedy
PCB = polychlorinated biphenyl
RM = river mile
SWAC = surface area-weighted average concentration

Table 8-10. Relative Benefit of Alternatives 3 and 4 Compared with Alternative 2

	Post-IR SWAC Based on CS 37	SWAC Reduction Relative to Pre-IR SWAC	Benefit Relative to Alternative 2	**Average Gross Erosional Flux** over 10-Year Post-IR Period (g/yr)		Benefit Relative to Alternative 2		**Total Water Column Load** at RM 8.3 over 10-Year Post-IR Period (g)		Benefit Relative to Alternative 2		**Average Concentration on Depositing Fine Sediment** over 10-Year Post-IR Period (ng/kg)		Benefit Relative to Alternative 2	
				Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
2,3,7,8-TCDD															
Alternative 2	80	91%	N/A	2.0	2.5	N/A	N/A	6.8	9.0	N/A	N/A	24	29	N/A	N/A
Alternative 3	70	92%	13%	1.9	2.4	6%	5%	6.3	8.2	7%	9%	23	28	5%	4%
Alternative 4	60	94%	25%	1.8	2.4	10%	5%	6.1	8.5	11%	6%	23	28	8%	5%

	Post-IR SWAC Based on CS 37	SWAC Reduction Relative to Pre-IR SWAC	Benefit Relative to Alternative 2	**Average Gross Erosional Flux** over 10-Year Post-IR Period (g/yr)		Benefit Relative to Alternative 2		**Total Water Column Load** at RM 8.3 over 10-Year Post-IR Period (g)		Benefit Relative to Alternative 2		**Average Concentration on Depositing Fine Sediment** over 10-Year Post-IR Period (mg/kg)		Benefit Relative to Alternative 2	
				Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Total PCBs															
Alternative 2	0.29	81%	N/A	25	26	N/A	N/A	135	138	N/A	N/A	0.43	0.45	N/A	N/A
Alternative 3	0.27	82%	7%	25	26	0.7%	0.1%	135	138	0.6%	0.3%	0.43	0.45	0.4%	-0.6%
Alternative 4	0.24	84%	17%	25	27	1.3%	-1.8%	134	139	1.2%	-0.5%	0.43	0.45	0.8%	-1.3%

Notes:

SWAC reduction relative to pre-IR SWAC is based on CS 37 SWAC values mapped to the model grid (932 ng/kg 2,3,7,8-TCDD; 1.5 mg/kg total PCBs).
Relative benefit is defined as the percentage reduction in SWAC or a given model metric relative to values shown for Alternative 2 for the same metric.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
IR = interim remedy
N/A = not applicable
PCB = polychlorinated biphenyl
RM = river mile
SWAC = surface area-weighted average concentration

Table 8-11. Average COC Concentration Delineating Incremental Remedial Footprint Areas

		Average Concentration in 0–0.5 ft			
		2,3,7,8-TCDD (ng/kg)		Total PCBs (mg/kg)	
Alternative	Target 2,3,7,8-TCDD SWAC (ng/kg)	In Remedial Footprint	In Incremental Area between Remedial Footprints	In Remedial Footprint	In Incremental Area between Remedial Footprints
2	85	2,870	--	3.8	0.58
3	75	2,570	220	3.7	0.62
4	65	2,400	170	3.3	0.6

Notes:

To delineate the remedial alternative footprints for the IR FS, the CS 37 base map was sampled on an 80-ft on center grid which reflects an assumed spatial density of the pre-design investigation. These concentrations are used to delineate the remedial alternative footprints, as described in more detail in Appendix B. The results in this table are averages of the 80-ft on center grid concentrations in the incremental area added between the alternatives.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

COC = chemical of concern

CS 37 = conditional simulation 37

IR FS = interim remedy feasibility study

PCB = polychlorinated biphenyl

SWAC = surface area-weighted average concentration

Table 8-12. Environmental Footprint Evaluation Metrics

Alternative	Description	GHG Emissions (metric ton)	Total Energy Used (MMBTU)	Water Consumption (gal)	Potential Injuries
1	No Action				
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm				
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm				
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm				
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL				

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
gal = gallon
GHG = greenhouse gas
MMBTU = million British thermal units
PCB = polychlorinated biphenyl
RAL = remedial action level
SWAC = surface area-weighted average concentration

APPENDIX A
DESIGN ASSUMPTIONS AND CONSTRUCTION QUANTITIES

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

Prepared for
Lower Passaic River Cooperating Parties Group
New Jersey

Prepared by

integral consulting inc.

September 2021

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
cy	cubic yard
LPR	Lower Passaic River
PCB	polychlorinated biphenyl
RAL	remedial action level
RM	river mile
SWAC	surface area-weighted average concentration
USACE	U.S. Army Corps of Engineers

1 INTRODUCTION

This appendix presents a summary of the design assumptions and construction quantities that describe the active alternatives presented in the Upper 9-Mile Source Control Interim Remedy Feasibility Study at the Lower Passaic River (LPR). Design assumptions and construction quantities are presented for the four active remedial alternatives:

- Alternative 2: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-interim remedy 2,3,7,8-TCDD SWAC of 85 ng/kg and PCB RAL of 1 mg/kg
- Alternative 3: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-interim remedy 2,3,7,8-TCDD SWAC of 75 ng/kg and PCB RAL of 1 mg/kg
- Alternative 4: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-interim remedy 2,3,7,8-TCDD SWAC of 65 ng/kg and PCB RAL of 1 mg/kg
- Alternative 5: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-interim remedy 2,3,7,8-TCDD SWAC of 125 ng/kg.

The following information is provided in this appendix:

- Dredging and capping quantities (Table A-1)
- Dredge production rates (Table A-2)
- Cap placement rates (Table A-3)
- Sediment processing and disposal parameters (Table A-4)
- Construction duration (Table A-5).

2 DREDGING AND CAPPING QUANTITIES

For the purposes of documenting the volume estimates, the river was separated into three areas, which correspond to specific dredging equipment and associated design assumptions. RM 8.3 and RM 14.9 denote the edges of the active remediation area. The areas were determined by the following river miles, based on the U.S. Army Corps of Engineers' (USACE's) system:

- RM 8.3 to 13.9 (Gregory Avenue Bridge)—Channel
- RM 8.3 to 13.9 (Gregory Avenue Bridge)—Shoals
- RM 13.9 to 14.9—Channel and Shoals.

From RM 13.9 to 14.9, it is assumed that land-based dredging equipment would be used regardless of channel/shoal delineation, due to the limited water access and site characteristics, so for the IR FS, no distinction is made between dredging and capping methods for the channel and shoals in this reach. Table A-1 provides a summary by area of the removal/capping areas and depths for the four active alternatives. The removal depth presented in the table for all alternatives is 2.5 ft, which includes a provision for a 0.5-ft overdredge allowance. Dredging volumes are based on the removal acreage and removal depths, and are presented by area in Table A-1.

Cap volumes are based on the removal acreage and the cap thickness. It is anticipated that cap thicknesses would range from approximately 2 ft (in low-energy areas) to approximately 2.5 ft (in areas subject to greater erosion potential). For cost estimation purposes, it is assumed that a 2.5 ft cap is placed, which includes a 0.5-ft-thick cap overplacement.

Final remedy dredging and capping configurations would be developed in the remedial design phase of the project.

3 DREDGE PRODUCTION RATES

The dredge production rates for the four active alternatives are presented in Table A-2. Experience from the Tierra Phase 1 removal action (Tierra 2013), RM 10.9 removal action (CH2M Hill 2019), and other large, industrialized river remediation projects suggests that mechanical dredging is an effective and productive dredging technique for the LPR.

The selection of representative equipment and production rates to be used for the purposes of this feasibility study is based, in part, on the consideration of various construction constraints, including:

- Bridges with low or limited crossing access, especially above RM 13.5
- Navigational constraints of shallow water or strong currents
- Migratory fish window limitations
- Critical structure protection.

The dredge production rates were calculated assuming the largest feasible dredge per area of the river, considering the constraints listed above to arrive at the following three options:

- Barge-based dredging with a 5 cubic yard (cy) environmental bucket
- Barge-based dredging with a 3 cy environmental bucket
- Land-based dredging with a 3 cy environmental bucket.

The production rates were calculated using the USACE (2008) standard equations found in Section 6.3.2 of the guidance document.

$$P_m = V_b * \left(\frac{60}{t_c}\right) * \left(\frac{f}{100}\right)$$

Where:

P_m	=	maximum operating production rate (mechanical) (cy/hr)
V_b	=	bucket size (cy)
f	=	bucket fill (percent)
t_c	=	cycle time (min)
60	=	conversion factor (min/hr)

And

$$P_o = P_m * EWTE$$

Where:

P_o = average operation production rate (mechanical) (cy/hr)
EWTE = effective work time efficiency

Average dredge uptime, bucket efficiency, and bucket cycle times are based on experience at other sites and are presented in Table A-2.

Refined estimates of dredge production rates would be developed in the remedial design phase of the project.

4 CAP PLACEMENT RATES

The cap placement rates for the four active alternatives are presented in Table A-3. The rates have been developed in a manner similar to that of the dredge production rates (Section 3), taking into account the same rate limiting factors associated with navigation and overwater construction operations on the LPR.

Depending on the river area, a 5 cy clamshell bucket operating from an appropriately sized deck barge, or a 3 cy clamshell bucket operated by land-based equipment was assumed for placement of cap materials. The cap placement rates were calculated using the USACE (2008) standard equations found in Section 6.3.2 of the guidance document, shown in Section 3.

Refined estimates of cap placement rates would be developed in the remedial design phase of the project.

5 SEDIMENT PROCESSING AND DISPOSAL

The sediment processing, water treatment, transportation, and disposal parameters for the four active alternatives are presented in Table A-4. The bases of these parameters are the dredging volumes presented in Table A-1 and the *in situ* sediment values presented in Table A-4.

Dredged sediment would be conveyed via barge to a commercial sediment processing facility (assumed to be Clean Earth for the purposes of the IR FS). Barge-dewatered effluent would be removed and transported to a separate water treatment facility, while sediment would be solidified and stabilized with an appropriate reagent admixture (e.g., Portland cement). Stabilized sediment would then be loaded into railcars for transportation to an offsite disposal facility.

Assumptions used in the processing and offsite disposal mass balance calculations are as follows (as listed in Table A-4):

- Five percent of dredge volume would be made up of oversized debris that would be separated before sediment is processed (based on the actual percentage of debris realized during the Tierra Phase 1 removal action [Tierra 2013]).
- Water would be entrained into the sediment during dredging at a proportion of 30% of sediment volume, based on final construction design report ratios of treated water to treated sediment during the LPR RM 10.9 removal action (CH2M Hill 2019).

Dredge material would be dewatered on the barge to the *in situ* solids content based on RI data (AQEA 2019), before processing. Final remedy processing and disposal amounts would be developed in the remedial design phase of the project.

6 CONSTRUCTION DURATION

The construction duration estimates for the four active alternatives are presented in Table A-5. The durations shown are based on the dredge volumes (Table A-1) and dredge production rates (Table A-2), given the following schedule assumptions:

- A nominal 0.1-year duration for mobilization.
- Effective dredge daily operating time of 22 hours/day, 6 days/week.
- Effective capping daily operating time of 11 hours/day, 6 days/week.
- Construction season of 183 days between July 1 and December 30. Due to the effective dredge weekly operating time, there can be up to 157 days of active dredging and/or capping during the construction season.
- Annual winter shutdown period of 60 days between January 1 and March 1, which could be necessitated by weather and/or operational delays.
- Dredging restriction to 121 days between March 1 to June 30 due to the fish migration window.
- Capping operations performed in parallel with dredging operations and beginning as soon as final bathymetric surveys of a completed dredge management area have been accepted by the regulatory agency. Dredge management areas would be defined during remedial design based on the remedial footprint and production rates.
- A nominal 0.5-year duration for capping following final dredging and demobilization.

A refined estimate of IR construction duration would be developed in the remedial design phase of the project.

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Tables

Table A-1. Dredging and Capping Quantities

Parameter	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Removal/Capping Areas (acres)				
RM 8.3 to RM 13.9 Channel	38	41	46	26
RM 8.3 to RM 13.9 Shoals	45	47	51	35
RM 13.9 to RM 14.9 Channel and Shoals	7	7	7	1
Total	**90**	**96**	**104**	**62**
Removal Depth (ft)				
RM 8.3 to RM 13.9 Channel	2.5	2.5	2.5	2.5
RM 8.3 to RM 13.9 Shoals	2.5	2.5	2.5	2.5
RM 13.9 to RM 14.9 Channel and Shoals	2.5	2.5	2.5	2.5
Volume of Dredged Materials (cy)[a]				
RM 8.3 to RM 13.9 Channel	155,000	167,000	184,000	104,000
RM 8.3 to RM 13.9 Shoals	180,000	191,000	205,000	142,000
RM 13.9 to RM 14.9 Channel and Shoals	28,000	29,000	30,000	3,000
Total	**363,000**	**387,000**	**419,000**	**250,000**
Volume of Capping Materials (cy)[a]				
RM 8.3 to RM 13.9 Channel	155,000	167,000	184,000	104,000
RM 8.3 to RM 13.9 Shoals	180,000	191,000	205,000	142,000
RM 13.9 to RM 14.9 Channel and Shoals	28,000	29,000	30,000	3,000
Total	**363,000**	**387,000**	**419,000**	**250,000**

Notes:
cy = cubic yard
ft = feet
RM = river mile
[a]Approximate totals are rounded to the nearest 1,000 cy.

Table A-2. Dredge Production Rates

Parameter	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Number and Size of Dredges				
RM 8.3 to RM 13.9	1 - 5 cy dredge	1 - 5 cy dredge	1 - 5 cy dredge	1 - 5 cy dredge
RM 8.3 to RM 13.9 Shoals	1 - 3 cy dredge	1 - 3 cy dredge	1 - 3 cy dredge	1 - 3 cy dredge
RM 13.9 to RM 14.9 Channel and Shoals	Land-based removal (3 cy bucket)	Land-based removal (3 cy bucket)	Land-based removal (3 cy bucket)	Land-based removal (3 cy bucket)
Small Dredge (3 cy Dredge)				
Average Dredge Uptime	55%	55%	55%	55%
Bucket Efficiency[a]	70 - 80%	70 - 80%	70 - 80%	70 - 80%
Bucket Cycle Time[b]	3 - 4 minutes	3 - 4 minutes	3 - 4 minutes	3 - 4 minutes
Medium Dredge (5 cy Dredge)				
Average Dredge Uptime	55%	55%	55%	55%
Bucket Efficiency	70 - 80%	70 - 80%	70 - 80%	70 - 80%
Bucket Cycle Time	3 - 4 minutes	3 - 4 minutes	3 - 4 minutes	3 - 4 minutes
Land-Based Dredge (3 cy Dredge)				
Average Dredge Uptime	55%	55%	55%	55%
Bucket Efficiency	70 - 80%	70 - 80%	70 - 80%	70 - 80%
Bucket Cycle Time	3 - 4 minutes	3 - 4 minutes	3 - 4 minutes	3 - 4 minutes
Dredge Operational Parameters				
Fish Window for Dredging	121 days (3/1-6/30)	121 days (3/1-6/30)	121 days (3/1-6/30)	121 days (3/1-6/30)
Annual Winter Shutdown	60 days (1/1-3/1)	60 days (1/1-3/1)	60 days (1/1-3/1)	60 days (1/1-3/1)
In-water Construction Period	183 days (7/1-12/30)	183 days (7/1-12/30)	183 days (7/1-12/30)	183 days (7/1-12/30)
Available Time for Dredging	24 hours/day	24 hours/day	24 hours/day	24 hours/day
Effective Dredge Daily Operating Time	22 hours/day	22 hours/day	22 hours/day	22 hours/day
Effective Dredge Weekly Operating Time	6 days/week	6 days/week	6 days/week	6 days/week
Dredging Production Rates (cy/day)[c]				
RM 8.3 to RM 13.9 Channel	813	813	813	813
RM 8.3 to RM 13.9 Shoals	476	476	476	476
RM 13.9 to RM 14.9 Channel and Shoals	476	476	476	476

Notes:

cy = cubic yard

NA = not applicable

RM = river mile

[a] Specific bucket efficiencies selected within range based on Adair (2004) and best professional judgment.

[b] Bucket cycle time range in accordance with U.S. Army Corps of Engineers guidelines (see note c). Specific bucket cycle times selected within range based on best professional judgment.

[c] USACE (2008; Chapter 6.3.2. Mechanical production rates based on operating parameters)

Table A-3. Cap Placement Rates

Parameter	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Number and Size of Dredges				
RM 8.3 to RM 13.9 Channel	1 - 5 cy dredge	1 - 5 cy dredge	1 - 5 cy dredge	1 - 5 cy dredge
RM 8.3 to RM 13.9 Shoals	1 - 5 cy dredge	1 - 5 cy dredge	1 - 5 cy dredge	1 - 5 cy dredge
RM 13.9 to RM 14.9 Channel and Shoals	Land-based removal (3 cy bucket)	Land-based removal (3 cy bucket)	Land-based removal (3 cy bucket)	Land-based removal (3 cy bucket)
Medium Dredge (5 cy Dredge)				
Average Dredge Uptime	70%	70%	70%	70%
Bucket Efficiency	90 - 95%	90 - 95%	90 - 95%	90 - 95%
Bucket Cycle Time	2 - 3 minutes	2 - 3 minutes	2 - 3 minutes	2 - 3 minutes
Land-Based Dredge (3 cy Dredge)				
Average Dredge Uptime	70%	70%	70%	70%
Bucket Efficiency	90 - 95%	90 - 95%	90 - 95%	90 - 95%
Bucket Cycle Time	2 - 3 minutes	2 - 3 minutes	2 - 3 minutes	2 - 3 minutes
Capping Operational Parameters				
Fish Window for Capping	121 days (3/1-6/30)	121 days (3/1-6/30)	121 days (3/1-6/30)	121 days (3/1-6/30)
Annual Winter Shutdown	60 days (1/1-3/1)	60 days (1/1-3/1)	60 days (1/1-3/1)	60 days (1/1-3/1)
In-Water Construction Period	183 days (7/1-12/30)	183 days (7/1-12/30)	183 days (7/1-12/30)	183 days (7/1-12/30)
Effective Capping Daily Operating Time	11 hours/day	11 hours/day	11 hours/day	11 hours/day
Effective Capping Weekly Operating Time	6 days/week	6 days/week	6 days/week	6 days/week
Capping Placement Rates (cy/day)[a]				
RM 8.3 to RM 13.9 Channel	1,041	1,041	1,041	1,041
RM 8.3 to RM 13.9 Shoals	1,041	1,041	1,041	1,041
RM 13.9 to RM 14.9 Channel and Shoals	520	520	520	520

Notes:
cy = cubic yard
RM = river mile
[a] USACE (2008; Chapter 6.3.2. Mechanical production rates based on operating parameters)

Table A-4. Sediment Processing and Disposal Quantities

Parameter	Alternative 2	Alternative 3	Alternative 4	Alternative 5
***In Situ* Sediment**				
Solids Content (% by weight)	56	56	56	56
Specific Gravity	1.51	1.51	1.51	1.51
Debris (% by volume)	5	5	5	5
Density of Debris (tons/cy)	2.0	2.0	2.0	2.0
Sediment Processing and Water Treatment				
Barge Dewatered Percent Solids (% by weight)	56	56	56	56
Ex Situ Sediment Volume to be Processed (cy)[a,b]	345,000	368,000	398,000	238,000
Entrained Water (% *in situ* Volume)	30	30	30	30
Treated Water (MG)	21	22	24	14
Transportation and Disposal				
Debris Disposal Weight (tons)[b]	36,000	39,000	42,000	25,000
Dewatered Sediment Disposal Weight (tons)[b]	456,000	486,000	527,000	314,000

Notes:
cy = cubic yard
MG = million gallons
[a]Debris is removed before processing sediment.
[b]Approximate totals are rounded to the nearest 1,000 cy or ton.

Table A-5. Construction Duration

Parameter	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Construction Duration (years)				
Mobilization	0.1	0.1	0.1	0.1
Dredging and Processing				
RM 8.3 to RM 13.9 Channel	1.1	1.2	1.3	0.8
RM 8.3 to RM 13.9 Shoals	2.2	2.4	2.6	1.8
RM 13.9 to RM 14.9 Channel and Shoals	0.4	0.4	0.4	0.0
Dredging and Processing Subtotal	3.7	4.0	4.3	2.6
Capping at End of Dredging and Demobilization	0.5	0.5	0.5	0.5
Total Construction Duration	**4.3**	**4.6**	**4.9**	**3.2**

Notes:
RM = river mile

Appendix B
Development of Remedial Alternatives Footprints

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ATTACHMENTS

Attachment 1 Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2

ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
cm	centimeter
cm/yr	centimeters per year
CS	conditional simulation
DU	Decision Unit
FS	feasibility study
IR	Interim Remedy
L	length
LPR	Lower Passaic River
M	mass
mg/kg	milligram per kilogram
ng/kg	nanograms per kilogram
PCB	polychlorinated biphenyl
RAL	Remedial Action Level
RAO	Remedial Action Objective
RI	remedial investigation
RM	river mile
ST	sediment transport
SWAC	surface-weighted average concentration
T	time
TCRA	time-critical removal action
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WY	water year

1 Introduction

1.1 Overview

This Appendix describes the delineation of remedial footprints for the four active remediation alternatives considered in the Interim Remedy Feasibility Study (IR FS). These alternatives are defined by their established target post-remedy 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) surface-weighted average concentrations (SWACs) of 85 nanograms per kilogram (ng/kg) (Alternative 2 in the IR FS), 75 ng/kg (Alternative 3), 65 ng/kg (Alternative 4), and 125 ng/kg (Alternative 5) for surface sediments between river mile (RM) 8.3 to RM 15[1]; the focus on 2,3,7,8-TCDD SWAC follows from Remedial Action Objective (RAO) 1, which specifies a maximum post-remedy SWAC of 85 ng/kg. The SWAC-based delineations for RAO 1 are subsequently expanded to include erosional areas of elevated subsurface (0.5 to 1.5 feet) concentration, as required by RAO 2. In addition to addressing 2,3,7,8-TCDD, three of the four active alternatives impose an established total polychlorinated biphenyl (PCB) Remedial Action Level (RAL) of 1 milligram per kilogram (mg/kg) in surface sediment and 2 mg/kg in subsurface sediment in erosional areas (only the 125 ng/kg alternative does not consider PCBs in developing the interim remedy footprint; however, this alternative would address PCBs to the extent that they are collocated with 2,3,7,8-TCDD). To understand mapping uncertainty, footprints were developed for 100 equally probable sediment concentration maps using conditional simulation (CS). The conditional simulation mapping is described in Appendix J of the Remedial Investigation (RI) Report (Anchor QEA et al. 2019, Appendix J). All the maps were used in a "desktop study" of remedial footprint characteristics (e.g., acreage and expected SWAC) and three were used in model projections. The maps used for model projections include one yielding the central tendency of SWAC, one likely yielding faster recovery in model projections and one likely yielding slower recovery. In both the desktop and modeling applications, particular focus was given to the central tendency map, termed CS 37.

The description of the remedial footprint delineation is organized as follows:

- Section 2 describes the concentration maps used in the delineations, the selection of CS 37 as a base map and the selection of two additional maps for model projections.
- Section 3 describes the sampling of the concentration maps and the development of the decision units used to delineate.
- Section 4 describes the approach to identifying remedial targets.
- Section 5 presents the resulting footprints.

[1] The U.S. Army Corps of Engineers (USACE) RM system is used in the present appendix, for consistency with the IR FS report convention. As such, the IR FS including this appendix uses a different RM system than the Lower Passaic River (LPR) Remedial Investigation (RI) (Anchor QEA et al. 2019). The USACE and U.S. Environmental Protection Agency (USEPA) RI RMs on the site differ by approximately 0.3 mile due to the specification of the zero RM location. An approximate conversion to RI RMs is to subtract 0.3 from the USACE RMs; the exact conversion varies along the river.

2 Maps of Sediment 2,3,7,8-TCDD and PCB Concentrations Used for Remedial Footprint Delineation

Concentration fields over the river bottom (i.e., concentration maps) were estimated for surface sediments (0 to 0.5 feet) and the underlying subsurface sediments (0.5 to 1.5 feet) using the RI data and geostatistical interpolation (Anchor QEA et al. 2019, Appendix J). For surface sediments, conditional simulation was used to generate 100 equally probable random realizations of the concentration field. Conditional simulation is based on kriging, which is an interpolation method that produces gridded estimates of contaminant concentrations and the uncertainty of those estimates (i.e., the prediction error) from the observed data and a variogram function that characterizes spatial correlation. Each of the 100 maps reproduces the mean and variance of the observed data and the covariance defined by the variogram. The measured concentrations at sampled locations are also honored, although some deviation may arise from the resolution of the grid and the assumed variance at very small separation distance. A corresponding map of subsurface concentrations in the 0.5 to 1.5 feet depth interval was generated by pairing the conditional simulation results at each interpolation grid cell with a data resampling technique that enforces the observed relationship between surface and subsurface concentrations (as described in Appendix J of the RI [Anchor QEA et al. 2019]. The method draws a subsurface concentration from a pool of sediment core data selected based on the mapped concentration in the overlying surface sediment).

The 100 CS maps allowed for the delineation of 100 footprints for each alternative, which are used to express key metrics such as remedial acreage, surface RAL, and expected post-remedy SWAC. CS 37 was chosen as the defining concentration map for the IR FS due to its central tendency among the 100 maps for remedial alternative metrics[2] and is the basis for figures and tables in the FS report unless otherwise noted.

2.1 Maps Used for Model Projections

Model projections of the five alternatives were limited to CS 37 and two additional maps (Anchor QEA 2019a) because long run times precluded running all 100 maps. CS 37 was chosen as the base map because its average 2,3,7,8-TCDD concentration is near the median of the 100 maps and the acreage targeted at a 2,3,7,8-TCDD RAL of 300 ng/kg (used in initial IR FS discussions with the U.S. Environmental Protection Agency [USEPA]) was near the central tendency among the maps. The two additional maps, CS 57 and CS 81, were chosen in collaboration with USEPA as maps likely to show faster and slower recovery in the model. The 75 ng/kg alternative (Alternative 3 in the IR FS)

[2] In Table 5-2, CS 37 is either the same as or close to the mean among the 100 simulations for the surface 2,3,7,8-TCDD RAL, post-remedy surface 2,3,7,8-TCDD SWAC, post-remedy subsurface 2,3,7,8-TCDD SWAC, surface 2,3,7,8-TCDD percent SWAC reduction, and remedial acreage.

was then delineated using these 2 maps and run through the projection model to provide mapping uncertainty bounds to the base projection results.

Because the four active alternatives would remove sediment from the target areas, 2,3,7,8-TCDD surface concentrations in non-target areas between RM 8.3-15 were evaluated to estimate the recovery potential for each alternative. Concentrations were examined based on model-predicted net deposition rates from water year (WY) 1996 to WY2010 for three categories:

1. Depositional areas defined by at least 0.1 centimeters per year (cm/yr) of net deposition.
2. Erosional areas defined by at least 0.1 cm/yr of net erosion.
3. Stable areas defined as a rate of net change less than 0.1 cm/year.

The WY1996 to WY2010 period was used to characterize the expected long-term behavior of the non-target areas in model projections because it corresponds to the hydrograph used in the projection simulations (it also corresponds to the main period considered in the calibration of long-term trends in the contaminant fate and transport model).

Surface 2,3,7,8-TCDD concentrations were evaluated for all three categories above. For erosional areas, subsurface 2,3,7,8-TCDD concentrations were evaluated as well due to the potential of being exposed through erosion. Concentrations were weighted by net volumetric sediment flux (F_S) using the following equations[3] applied on a Decision Unit (DU) basis, i.e., the polygons used to define remedial targets (see next section).

Equation 1

$$F_{S,n} = A_n * R_{S,n}$$

where:

$F_{S,n}$	=	volumetric sediment flux (L^3/T) for DU *n*
A_n	=	area (L^2) of DU *n*
$R_{S,n}$	=	model-predicted net sediment erosion or deposition rate (L/T) of DU *n*

[3] Units in Equations 1 and 2 are expressed dimensionally in terms of mass (M), length (L), and time (T).

Equation 2

$$C_W = \frac{\sum_{n=1}^{N} F_{S,n} * C_n}{\sum_{n=1}^{N} F_{S,n}}$$

where:

C_W	=	weighted 2,3,7,8-TCDD concentration (M/M)
C_n	=	2,3,7,8-TCDD concentration (M/M) of DU *n* (surface and subsurface concentrations are used here, depending on the analysis)
N	=	number of non-target area DUs

Figure 2-1 compares weighted surface (0 to 0.5 feet) 2,3,7,8-TCDD concentrations in non-target depositional and erosional areas defined over the 1995 to 2010 period for all 100 conditional simulations. Conditional simulation identification numbers are labeled on the plot. Greater recovery potential likely exists where weighted depositional area concentration is high and weighted erosional area concentration is low. Conversely, lesser recovery potential likely exists where weighted depositional area concentration is low and weighted erosional area concentration is high. CS 57 is notable for more recovery and CS 81 for less recovery compared to CS 37; CS 37 is near the middle on the 1995 to 2010 panel.

Figure 2-2 compares weighted 2,3,7,8-TCDD concentrations in non-target erosional areas for subsurface sediments (0.5 to 1.5 feet) and surface sediments (0 to 0.5 feet). Simulations with more recovery would likely have lower concentrations in both surface and subsurface. Lower subsurface concentrations represent less impact if exposed during erosion. Lower surface concentrations represent a lower potential to cause recontamination during erosional events. Conversely, higher concentrations in both surface and subsurface sediments likely represent less recovery. CS 57 is notable for more recovery for both time periods of study. CS 81 is notable for less recovery in surface concentrations while being near the middle in terms of recovery for subsurface concentrations. CS 37 is near the middle for 1995 to 2010 surface recovery, but showing more recovery based on other metrics on this figure.

Figure 2-3 illustrates weighted surface sediment 2,3,7,8-TCDD concentrations in stable non-target areas. The relationship between recovery and concentration in stable areas is unclear; while high concentration sediments may locally experience recovery via periodic erosion/deposition (by dilution of surface sediments and contaminant loss to the water column), this process may also inhibit recovery elsewhere by transferring contaminant to other sediment areas via the water column. Note that CS 37 is also near the central tendency in these comparisons.

The above analyses support CS 37 as being representative of the central tendency with respect to recovery potential. The concentration patterns in depositional and erosional areas suggest that, compared to CS 37, CS 81 has less recovery potential and CS 57 has more recovery potential. Therefore, these three CS maps were selected to evaluate how model projections are impacted by contaminant mapping uncertainty.

3 Sampling of Maps and Establishment of Decision Units for Delineation

The maps were not used directly to draw remedial footprints because that would reflect an unrealistic fine-scale knowledge of the contaminant concentration field that is not credible for remedy implementation and could overstate the remedial benefit of the alternatives. Rather, remedial targets were identified using a subsample of the concentrations on the maps.

In order to mimic the first phase of high-density sampling that is anticipated for remedial design, the conditional simulation maps were sampled on an approximate 80-foot triangular grid. The vertices of this grid were termed the center-points. The locations of individual center-points on the grid were adjusted, where needed, to provide adequate coverage of each of the geomorphic groups used in the underlying contaminant mapping (i.e., silt areas were separated from non-silt areas, and channels and shoals were separated in non-silt areas; see Appendix J of the RI [Anchor QEA et al. 2019]). The conditional simulation maps were sampled at the locations closest to the center-points (Figures 3-1a through e) and the sampled concentration was assigned to each center-point. Thiessen polygons were constructed around each center-point, adjusting for geomorphic boundaries (Figures 3-1a through e). Each polygon is an assigned area of influence for the center-point sample and is termed a Decision Unit (DU). Targeting is then done at the DU scale. In addition to the center-point concentration used for targeting, each DU was assigned a "true mean" concentration based on the arithmetic average of the map concentrations within the DU. This true mean concentration is used to compute the expected post-remedy SWAC for a given footprint (i.e., the remedial benefit realized by targeting areas based on the DU center-point concentrations).

4 Identifying Remediation Targets

Target areas for remediation between RM 8.3 to RM 15 were identified in a two-step process. First, DUs were targeted based on surface (0 to 0.5 feet) sediment concentrations to achieve the target SWAC (RAO 1). Second, the target areas were expanded to include erosional areas with elevated subsurface (0.5 to 1.5 feet) concentrations, as required by RAO 2.

4.1 Targeting to Achieve the Target SWAC

Target areas were identified by first selecting DUs with center-point concentrations above the PCB RAL (1 mg/kg for all but the 125 ng/kg target SWAC alternative) and then "hill-topping" 2,3,7,8-TCDD concentrations to achieve the target post-remedy SWAC (125 ng/kg, 85 ng/kg, 75 ng/kg, or 65 ng/kg depending on the alternative). The hill-topping process involves targeting DU polygons in order of decreasing center-point 2,3,7,8-TCDD concentration until the calculated post-remedy SWAC falls below the target SWAC for each alternative. In this process, targeted DUs were assigned a residual 2,3,7,8-TCDD concentration of 10 ng/kg (reflecting an assumed level of recontamination) and untargeted DUs were assigned the true mean concentration of the underlying conditional simulation map.

The implication of using DU center-point concentrations to delineate targets is that there are embedded "targeting errors" in the footprint delineations. Targeting errors include instances where the true DU mean concentration exceeds the RAL but the DU is not remediated due to a low center-point concentration and the inverse case where the center-point concentration exceeds the RAL but the true DU mean concentration does not. These targeting errors are intentional and meant to conservatively reflect the limitations of the design data to resolve fine-scale concentration patterns.

The hill-topping process yields the surface sediment 2,3,7,8-TCDD RAL for each alternative (the RAL is map-specific). This RAL is defined as the last DU center-point concentration remediated to achieve the target SWAC, rounded down to an integer (i.e., DUs with center-point concentrations greater than or equal to the RAL are remediated).

4.1.1 Hill-Topping Treatment Near the RM 10.9 Time-Critical Removal Action

Areas that were remediated as part of the RM 10.9 time-critical removal action (TCRA) were assigned a 2,3,7,8-TCDD concentration of 227 ng/kg which is the arithmetic average of the post-remedy samples within the dredged and capped footprint[4]. Table 4-1 lists the data used in this average (AECOM 2016; USEPA and USACE 2019). Because this area has already been remediated, it was

[4] For the purpose of calculating total PCB post-remedy SWACs, areas that were remediated as part of the RM 10.9 TCRA were assigned a total PCB concentration of 0.57 mg/kg.

excluded from IR FS remediation but is included in the post-remedy SWAC for the hill-topping procedure. Nearshore areas between the south-eastern edge of the RM 10.9 removal area footprint and the shoreline (Figure 4-1) were also excluded from remediation, because these nearshore areas tended to be rocky and did not contain elevated measured concentrations. The utility corridor and a fingertip region originally part of the TCRA removal area but not remediated were assumed to be eligible for remediation during the hill-topping (Figure 4-1) (USEPA 2019a).

4.2 Targeting Areas for RAO 2

RAO 2 target areas were delineated by first identifying DU polygons with center-point subsurface concentrations greater than twice the surface sediment PCB or 2,3,7,8-TCDD RALs[5], and then adding to the remedy footprint any portion of these DUs that lie within erosional areas.[6] Because erosional areas were defined somewhat differently for the "desktop study" evaluations and the model projections, this step yields two versions of each footprint. Discussed below are the rationale for using twice the surface sediment RAL and the approaches used to identify erosional areas.

4.2.1 Rationale for Setting the Subsurface RAL to Twice the Surface RAL

The subsurface RAL for RAO 2 was established by USEPA and CPG and was set to twice the surface RAL for both 2,3,7,8-TCDD and total PCBs (USEPA 2019a) as a site management decision. As described in Anchor QEA (2019b) (included herein as Attachment 1), the rationale for using a higher subsurface RAL in areas that exhibited erosion is that the probability of further erosion is less than 100%. Setting the subsurface RAL to two times the surface RAL is analogous to assuming that there is a 50% chance of enough additional erosion to expose the subsurface (0.5 to 1.5 feet) sediments. The likelihood of erosional areas experiencing subsequent erosion was evaluated using changes in bathymetry between multibeam bathymetric surveys. To this end, areas with at least 0.5 feet of erosion between the 2008 and 2010 surveys were identified as test locations (this period included a 25-year high flow event in March 2010, shortly before the 2010 survey). The change in bathymetry between 2011 and 2012 at these test locations was also examined to assess the impact of Hurricane Irene, a 90-year flow event that occurred shortly before the 2011 survey. These comparisons indicate that areas that exhibited 0.5 feet or more of erosion between 2008 and 2010 had approximately a 25% probability of eroding another 0.5 feet or more during Hurricane Irene. This supports using a 4x multiplier for the RAO 2 subsurface RAL, but a 2x multiplier was adopted to be conservative. See Attachment 1 for additional details of the analysis and the rationale for the subsurface RAL multiplier.

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[5] The PCB surface RAL is 1 mg/kg for all but the 125 ng/kg target SWAC alternative (which has no PCB RAL) and the 2,3,7,8-TCDD RAL is determined by the hill-topping process described in Section 4.1.

[6] The Thiessen polygon-based delineation assigns the center-point concentrations to the entire polygon. If a portion of a polygon is erosional, then the decision of whether to include that portion in the delineation is based on the assigned center-point concentrations.

4.2.2 Probabilistic Analysis of the Impact on Post-Remedy SWAC of Erosion Exposing Concentrations Between the RAL and Twice the RAL

A Monte Carlo analysis was performed to assess whether not targeting erosional areas with subsurface concentrations up to twice the surface 2,3,7,8-TCDD RAL could compromise attaining the target SWAC if those concentrations were to reach the sediment surface via erosion. The analysis considered three of the four active remediation alternatives included in the IR FS, defined by target 2,3,7,8-TCDD post-remedy SWACs of 85 ng/kg, 75 ng/kg, and 65 ng/kg (i.e., Alternatives 2 through 4). The analysis evaluated the impact of increasing surface sediment concentrations in 25%, 50%, 75%, and 100% of the identified erosional area (see Section 4.2.3) to concentrations above the surface RAL but less than twice the surface RAL (i.e., between the surface and subsurface RALs). The erosional area concentrations were drawn at random from this concentration range for each alternative using a uniform distribution. For each alternative and fractional area eroded, a distribution of 2,3,7,8-TCDD post-remedy SWACs was calculated by area-weighting the erosional area concentrations with the SWAC of the remaining area between RM 8.3 to 15 (the latter is assumed to be equal to the original post-remedy SWAC calculated assuming erosion does not occur). This distribution is compared to the target post-remedy SWAC for the alternative to assess the potential impact of subsurface concentrations becoming exposed during an erosional event.

The input parameters of the analysis include the acreage of the additional erosional areas[7], which varies between 2 and 3 acres, the post-remedy SWAC calculated assuming that erosion does not occur, and the surface and subsurface 2,3,7,8-TCDD RALs.[8] The table included in Figure 4-2 summarizes the values used for the input parameters for each alternative.

Figure 4-2 summarizes the results of the Monte Carlo simulations. Each of the three plots presented in the figure shows the probability distribution of the 2,3,7,8-TCDD post-remedy SWAC for a specific alternative for each of the four levels of erosion evaluated (defined above). The results indicate that even when 100% of the erosional area are exposed and have the highest concentrations (e.g., just below twice the surface RAL), the 2,3,7,8-TCDD post-remedy SWAC remains below the target post-remedy SWAC for all the alternatives considered. The likelihood of 100% erosion across all erosional areas and all concentrations in these eroded areas being just below twice the surface RAL is small, thereby further supporting the use of twice the surface RAL as the trigger for remediation for erosional area subsurface sediments.

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[7] The erosional area acreage is here the area that would be added to the footprint if the RAO 2 2,3,7,8-TCDD subsurface RAL were decreased from 2x to 1x the RAO 1 2,3,7,8-TCDD surface RAL.

[8] For each alternative, the subsurface RAL was set to twice the surface RALs in accordance with the results of the analysis described in Section 4.2.1,

4.2.3 Identifying Erosional Areas where RAO 2 Will Be Applied

Two methods were used to identify erosional areas, resulting in two versions of the remedial footprint added by RAO 2.[9] The first method was used in the "desktop study" of 100 conditional simulation maps that characterizes the uncertainty in the remedial statistics. In this case, erosional areas were identified using a hybrid data/model approach that relied on bathymetric survey differencing data where available, and sediment transport (ST) model predictions in areas lacking bathymetry data. The second method was used in model projections and was designed for compatibility with the projection modeling. For this version, erosional areas were identified based on ST model predictions alone.

4.2.3.1 Hybrid Data/Model Definition of Erosional Areas for "Desktop Study" Calculations

For the "desktop study" calculations, erosional areas were defined as experiencing at least 0.5 feet of net erosion in sequential bathymetric comparisons in the period from 2007 to 2012 (a period that includes Hurricane Irene) using multibeam bathymetric survey data where available (mainly in the channel and covering about 65% of the river) and model predictions for remaining areas. Multibeam bathymetry erosional areas were based on elevation changes between the 2007, 2008, 2010, 2011, and 2012 surveys; specifically, the "Erosion" and "Erosion and Deposition" bathymetric change categories developed in Section 4 of the RI Report (Anchor QEA et al. 2019) were used. In areas where multibeam bathymetry data were lacking, erosional areas were identified as grid cells for which the USEPA-approved CPG RI/FS sediment transport model indicated a maximum erosion of at least 15 centimeters (cm) after Hurricane Irene[10] (USEPA 2019b). Figure 4-3a through e shows the erosional areas used in the hybrid method for the "desktop study."

4.2.3.2 Model Only Definition of Erosional Areas for Model Projections

For the second of the two methods (for model projections), erosional areas were defined using the ST model long-term erosion rates from the calibration period between WY1996 and WY2010. This period was selected because it uses the same hydrograph as the FS model projections and is thus expected to reflect similar erosion behaviors as the projection runs (the full model calibration period WY1996 to WY2013 was not used because it includes the effect of Hurricane Irene, which is not part of the projection hydrograph). The ST model erosion rates are averages within grid cells at the resolution of the model. Within a grid cell, the distribution of erosion rates would include rates higher than the average and perhaps higher than 0.5 feet (15 cm). The average corresponding to a

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[9] The surface sediment target SWAC footprint methodology is the same for the "desktop study" and the model projection inputs.

[10] Formally, the maximum erosion during each of the three highest high flow events in the 2007 to 2012 period (i.e., the period of the multibeam surveys) was considered in identifying model-based erosional areas: March 2010, March 2011, and Hurricane Irene (August 2011). However, the model only predicted erosion of 15 cm or more during Hurricane Irene and thus its response to that event determined the erosional areas in the "desktop study".

significant fraction of the distribution being 0.5 feet or higher is unknown. A long-term erosion rate threshold of 0.42 cm/yr was chosen so as to yield RAO 2 footprint acreages consistent with the hybrid data/model approach used in the "desktop study" (Section 4.2.3.1). This threshold is intended to roughly capture areas that might be subject to 15 cm or more of erosion (the criteria used in the hybrid data/model approach) during a long-term projection period but is obviously uncertain. An additional uncertainty comes from the model's non-linear response to storm events (erosion patterns may differ between events or between calibration and projection due to different antecedent bed properties as the bed evolves over time in the model). Figure 4-4a through e shows the erosional areas used for model projection footprint delineation.

5 Resulting Footprints

The procedures described above were applied to the base map (CS 37) to determine the 2,3,7,8-TCDD RAL, the remedial acreage and the expected post-remedy SWAC. The procedure was also applied to the remaining 99 conditional simulations in order to characterize the range of expected remedial acreages and post-remedy SWACs for the "desktop study." For the model projections, the procedures were applied to CS 37 for all four target SWAC alternatives and to CS 57 and CS 81 for the 75 ng/kg target SWAC scenario.

Table 5-1 lists the RALs and compares the overall RAO1 and RAO 2 CS 37 footprint acreages for the "desktop study" with the model projection footprint. Table 5-2 lists the range across all 100 conditional simulations from the "desktop study." Table 5-3 lists the footprint acreages delineated using CS 57 and CS 81 for the model projection sensitivity. Figures 7-2 through 7-5 in the main report show the CS 37 footprints for the "desktop study." Figures 5-1a–e through 5-6a–e show the footprints using model-based erosional areas for the four active remedy alternatives using CS 37 as well as for the 75 ng/kg alternative using CS 57 and CS 81 for the model projections.

6 References

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Tables

Table 4-1
Post-Remedy Samples within the RM 10.9 Removal Area

Programs	Location ID	2,3,7,8-TCDD (ng/kg)
2015 ERT	PRSS-01	310
	PRSS-02	310
	PRSS-03	680
	PRSS-05	290
	PRSS-06	150
	PRSS-07	150
2016 CPG	16A-0601	196
	16A-0602	218
	16A-0603	232
	16A-0604	199
	16A-0605	215
	16A-0606	225
	16A-0607	195
	16A-0608	51.5
	16A-0609	39.9
	16A-0610	167

Notes:

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

CPG: Cooperating Parties Group

ERT: Environmental Response Team

ID: identification

ng/kg: nanograms per kilogram

Table 5-1

Remedial Acreages for RAO 1 and RAO 2 Delineated Using CS 37 for the "Desktop Study" and the Projection Model

IR FS Alternative	Target Post-Remedy 2,3,7,8-TCDD SWAC (ng/kg)[1]	2,3,7,8-TCDD RALs (ng/kg)		"Desktop Study"				Projection Model			
		RAO 1 Surface (0-0.5 ft)	RAO 2 Subsurface (0.5-1.5 ft)	2,3,7,8-TCDD Post-Remedy SWAC (ng/kg)	Acres			2,3,7,8-TCDD Post-Remedy SWAC (ng/kg)	Acres		
					RAO 1	RAO 2	Total		RAO 1	RAO 2	Total
2	85	260	520	80	85	5	90	80	85	5	90
3	75	205	410	70	91	5	96	70	91	6	96
4	65	164	328	60	98	6	104	60	98	6	104
5	125	346	692	121	59	3	62	122	59	3	62

Notes:

1. This column is the target post-remedy 2,3,7,8-TCDD SWAC for RAO 1. Alternatives 2-4 include a total PCB RAL of 1. Alternative 5 does not include a total PCB RAL.

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

CS: conditional simulation

FS: feasibility study

ft: feet

IR: Interim Remedy

ng/kg: nanograms per kilogram

PCB: polychlorinated biphenyl

RAL: Remedial Action Level

RAO: Remedial Action Objective

SWAC: surface-weighted average concentration

Table 5-2

Range and Mean for Remedial Acreages, Post-Remedy SWACs, and RALs for All 100 Simulations in the "Desktop Study"

IR FS Alternative	2,3,7,8-TCDD SWAC Target (ng/kg)[1]	Map Statistic	Surface RAL for 2,3,7,8-TCDD (ng/kg)	Post-Remedy Surface 2,3,7,8-TCDD SWAC (ng/kg)	Post-Remedy Subsurface 2,3,7,8-TCDD SWAC (ng/kg)	Surface 2,3,7,8-TCDD SWAC Reduction (%)	Remedial Acreage
2	85	CS 37	260	80	239	92	90
		Mean	250	80	226	91	88
		Range	183-352	76-82	191-255	88-94	74-106
3	75	CS 37	205	70	207	93	96
		Mean	198	70	196	92	95
		Range	144-275	66-73	173-222	89-95	79-115
4	65	CS 37	164	60	169	94	104
		Mean	158	61	168	93	102
		Range	115-212	55-63	147-193	90-96	87-122
5	125	CS 37	346	121	354	88	62
		Mean	345	120	344	86	61
		Range	256-470	115-123	297-384	82-92	44-75

Notes:

1. This column is the target post-remedy 2,3,7,8-TCDD SWAC for RAO 1. Alternatives 2-4 include a total PCB RAL of 1. Alternative 5 does not include a total PCB RAL.

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

CS: conditional simulation

FS: feasibility study

IR: Interim Remedy

ng/kg: nanograms per kilogram

PCB: polychlorinated biphenyl

RAL: Remedial Action Level

SWAC: surface-weighted average concentration

Table 5-3
Comparison of Remedial Acreages, Post-Remedy SWACs, and RALs for CS 57 and CS 81 for the Model Projections

IR FS Alternative	Target Post-Remedy 2,3,7,8-TCDD Surface SWAC (ng/kg)[1]	CS 57						CS 81					
		2,3,7,8-TCDD RALs (ng/kg)		2,3,7,8-TCDD Post-Remedy Surface SWAC (ng/kg)	Acres			2,3,7,8-TCDD RALs (ng/kg)		2,3,7,8-TCDD Post-Remedy Surface SWAC (ng/kg)	Acres		
		RAO 1 Surface (0-0.5 ft)	RAO 2 Subsurface (0.5-1.5 ft)		RAO 1	RAO 2	Total	RAO 1 Surface (0-0.5 ft)	RAO 2 Subsurface (0.5-1.5 ft)		RAO 1	RAO 2	Total
2	85	255	510	80	82	6	88	215	430	81	91	6	97
3	75	191	382	71	89	7	95	170	340	70	98	6	105
4	65	150	300	62	97	6	103	153	306	61	103	6	109
5	125	316	632	123	57	2	59	337	674	119	64	3	67

Notes:

1. This column is the target post-remedy 2,3,7,8-TCDD SWAC for RAO 1. Alternatives 2-4 include a total PCB RAL of 1. Alternative 5 does not include a total PCB RAL.

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

CS: conditional simulation

FS: feasibility study

ft: feet

IR: Interim Remedy

ng/kg: nanograms per kilogram

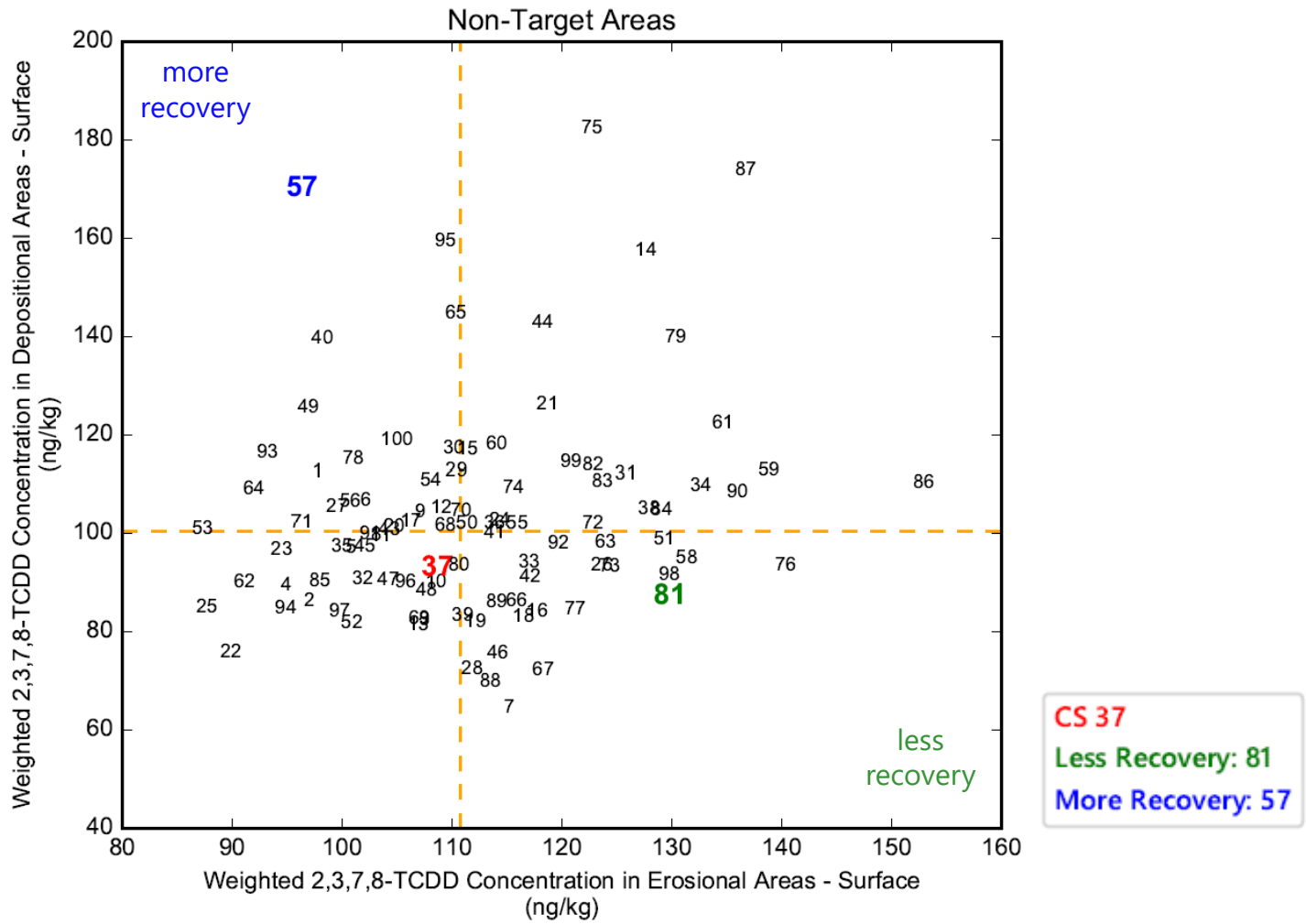
PCB: polychlorinated biphenyl

RAL: Remedial Action Level

RAO: Remedial Action Objective

SWAC: surface-weighted average concentration

Figures



Notes: RM 8-14.7. Target areas were identified using center-point delineation with the following RALs: 2,3,7,8 TCDD >= 205.0 ng/kg or Total PCB >= 1.0 mg/kg. The non-target areas are outside the target area delineation with <=-0.1 and >=0.1 cm/yr deposition. Concentration weighted by area and deposition rate. Dashed line represents the median value.
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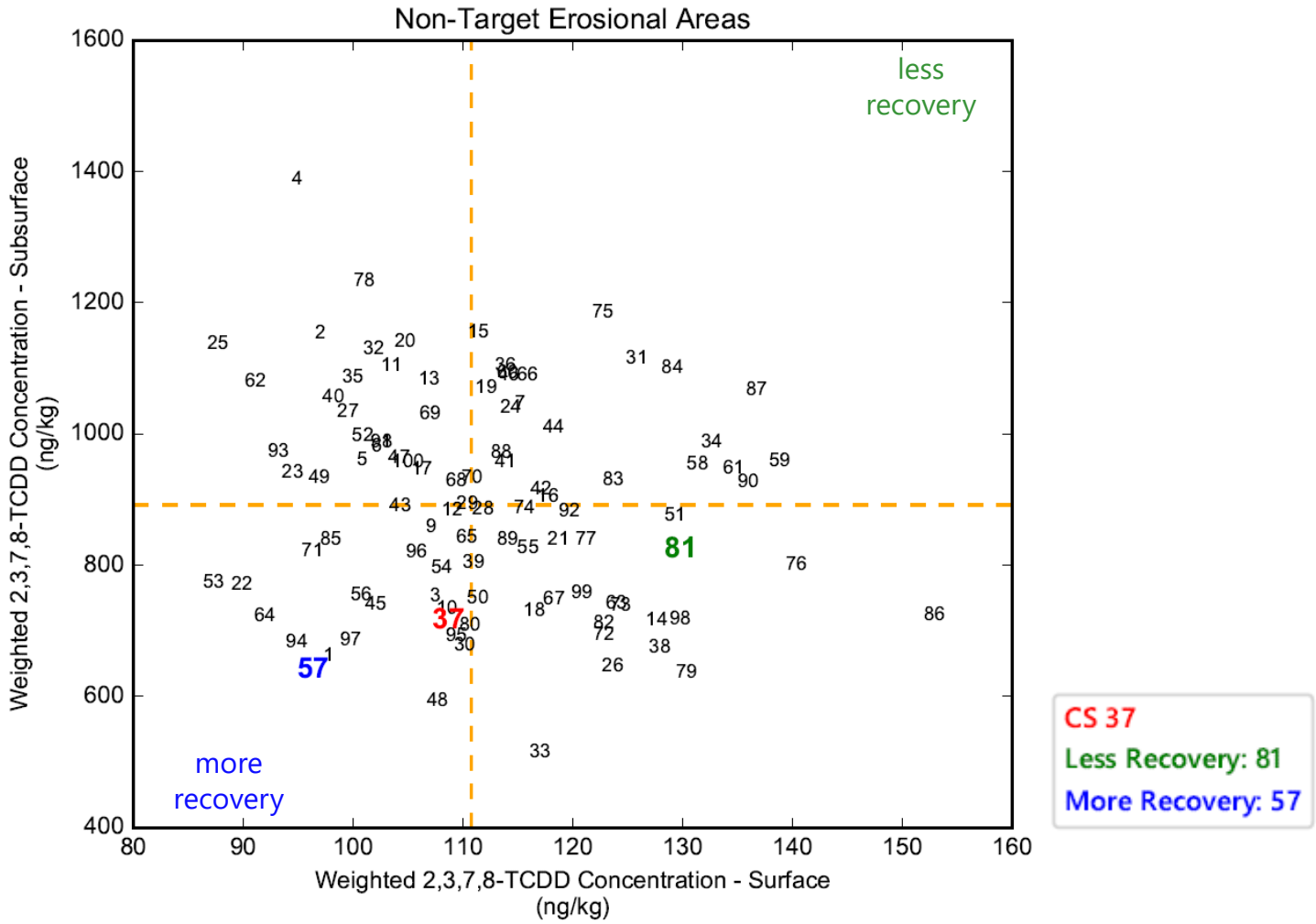
Figure 2-1
Non-Target Areas: Comparison of Surface Concentrations in Depositional and Erosional Areas (1995-2010)
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



Notes: RM 8-14.7. Target areas were identified using center-point delineation with the following RALs: 2,3,7,8 TCDD >= 205.0 ng/kg or Total PCB >= 1.0 mg/kg. The non-target areas are outside the target area delineation with <=-0.1 cm/yr deposition.
Concentration weighted by area and deposition rate. Dashed line represents the median value.
Conditional Simulation of 2,3,7,8 TCDD: k20160909_RI_draft2\plots/tcdd2378_adj/v1_gaussian/a5_lg_grid

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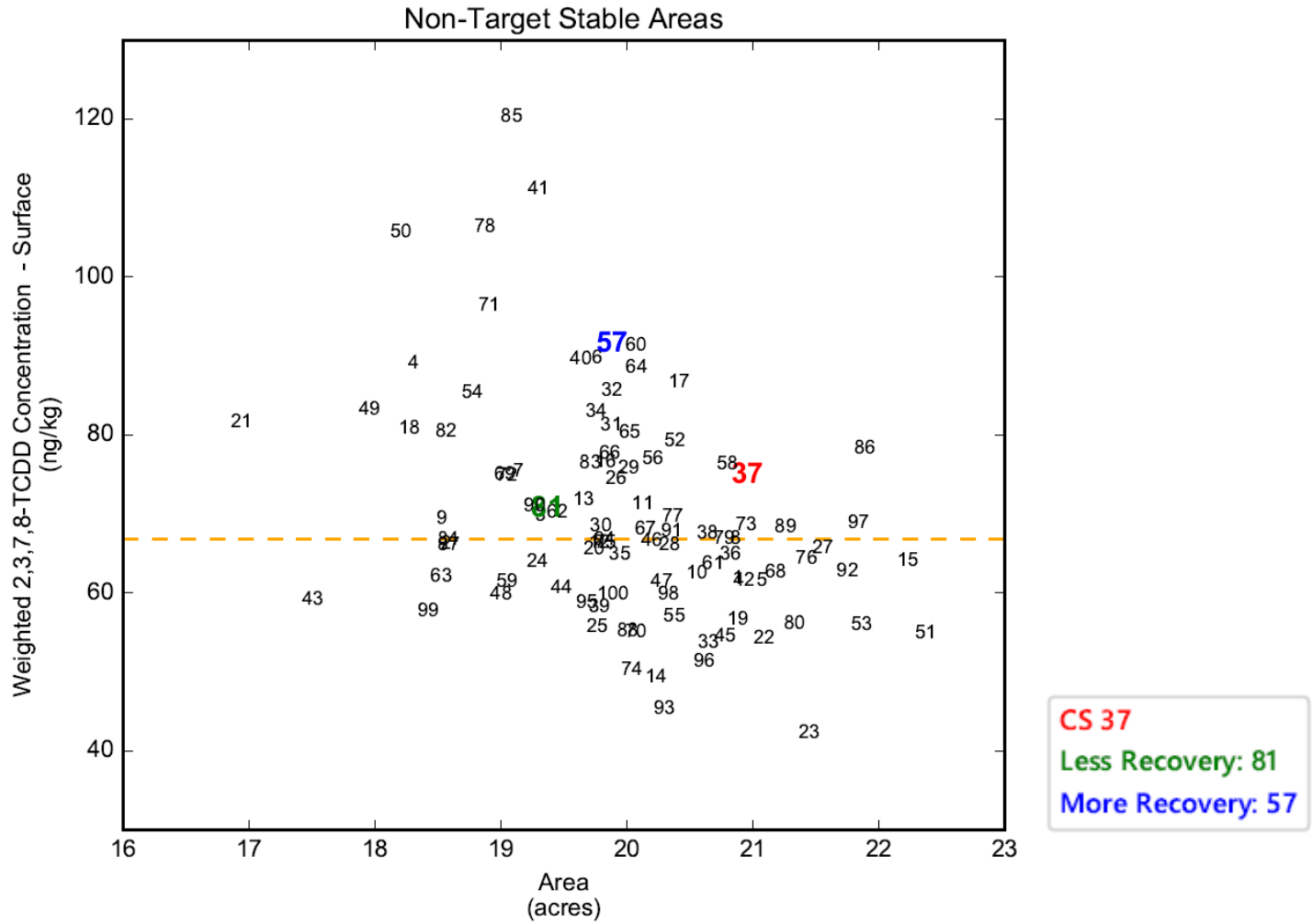
Figure 2-2

Non-Target Areas: Comparison of Subsurface and Surface Concentrations in Erosional Areas (1995-2010)

Upper 9 Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area



Notes: RM 8-14.7. Target areas were identified using center-point delineation with the following RALs: 2,3,7,8 TCDD >= 205.0 ng/kg or Total PCB >= 1.0 mg/kg. The non-target areas are outside the target area delineation with <=-0.1 and >=0.1 cm/yr deposition. Concentration weighted by area and deposition rate. Dashed line represents the median value.
Conditional Simulation of 2,3,7,8 TCDD: k20160909_RI_draft2\plots/tcdd2378_adj/v1_gaussian/a5_lg_grid

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Figure 2-3

Non-Target Areas: Comparison of Surface Concentrations and Acreage in Stable Areas (1995-2010)

Upper 9 Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area

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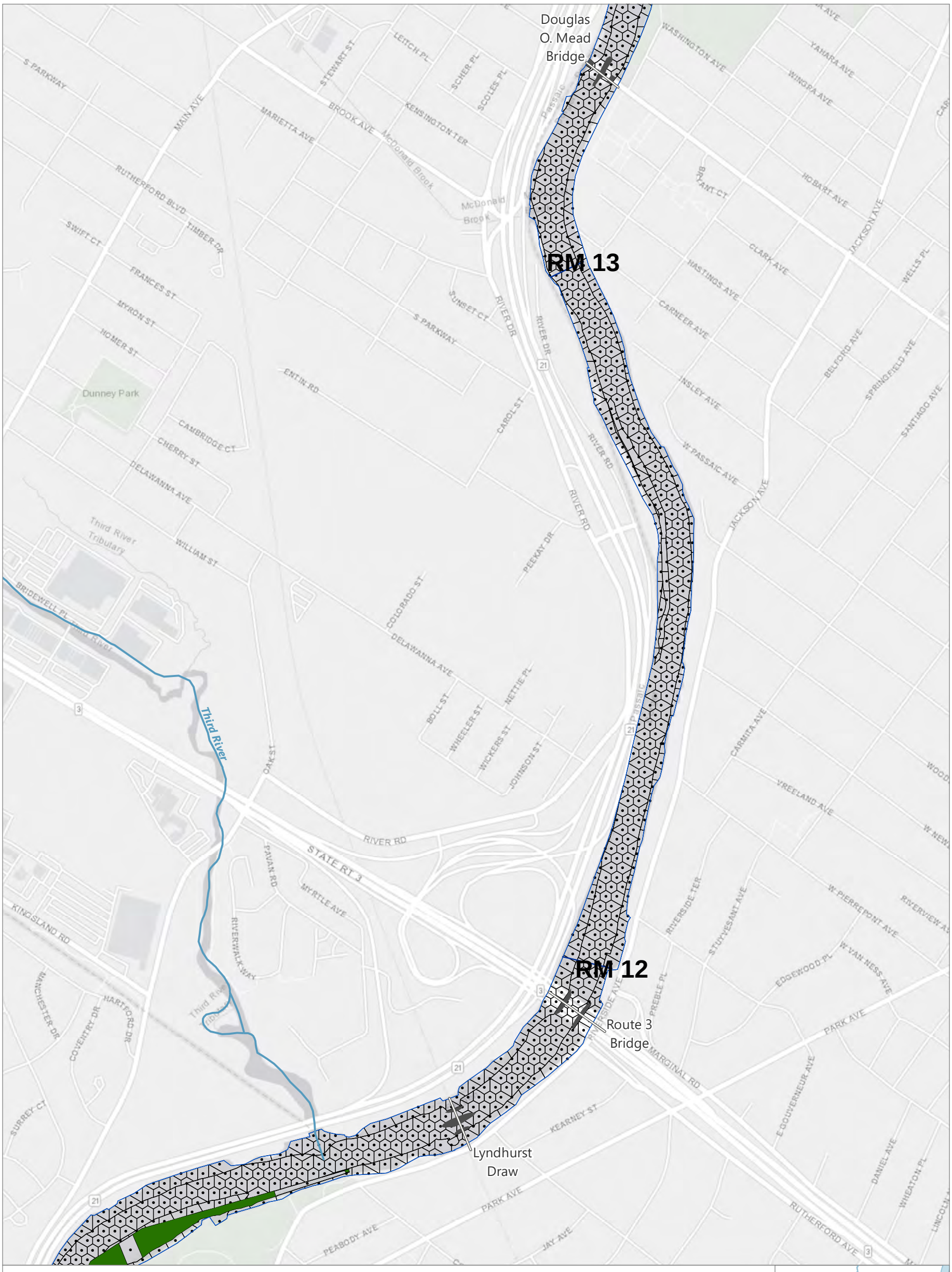
Figure 3-1a
Decision Units (DUs) and Their Centerpoints
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Tributaries
- Bridge
- Bridge Abutment
- Center-Points
- DUs
- TCRA Remediated in 2013-2014

NOTE(S):
The TCRA Area was subjected to remediation in 2013-2014

0 1,140
Feet

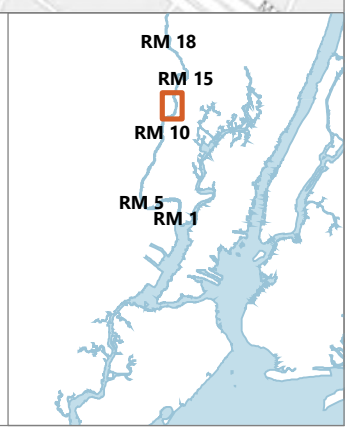


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Figure 3-1b
Decision Units (DUs) and Their Centerpoints
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

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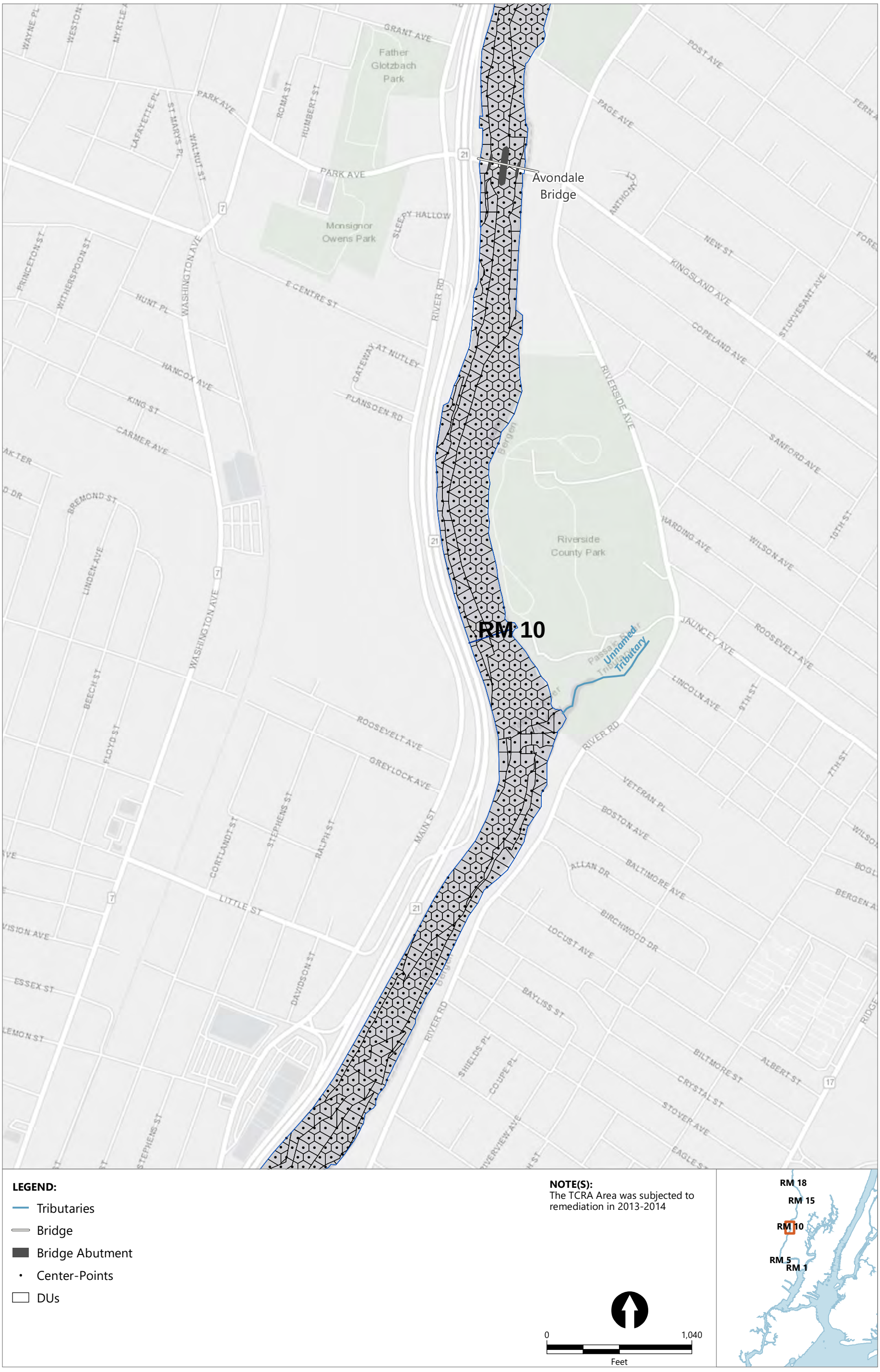
Figure 3-1c
Decision Units (DUs) and Their Centerpoints
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Tributaries
- Bridge
- Bridge Abutment
- Center-Points
- DUs

NOTE(S):
The TCRA Area was subjected to remediation in 2013-2014

0 1,040
Feet

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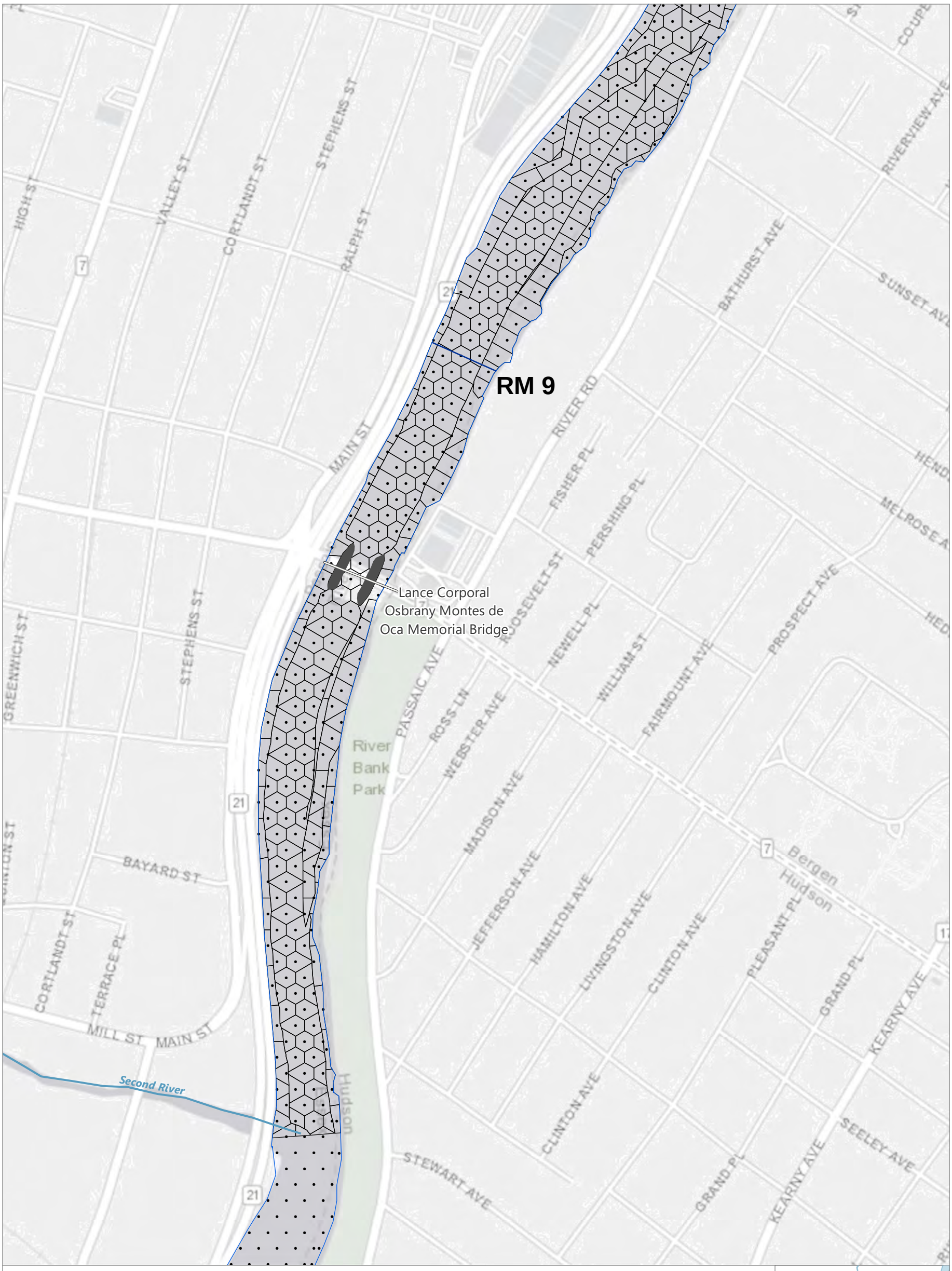
Figure 3-1d
Decision Units (DUs) and Their Centerpoints
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Tributaries
- Bridge
- Bridge Abutment
- Center-Points
- DUs

NOTE(S):
The TCRA Area was subjected to remediation in 2013-2014

0 700
Feet

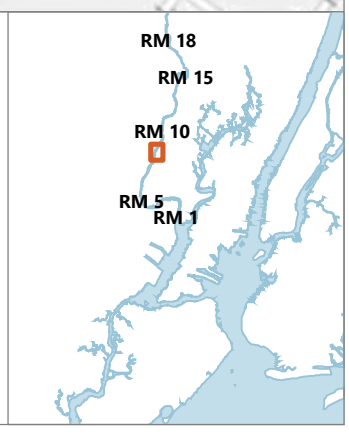


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Figure 3-1e
Decision Units (DUs) and Their Centerpoints
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

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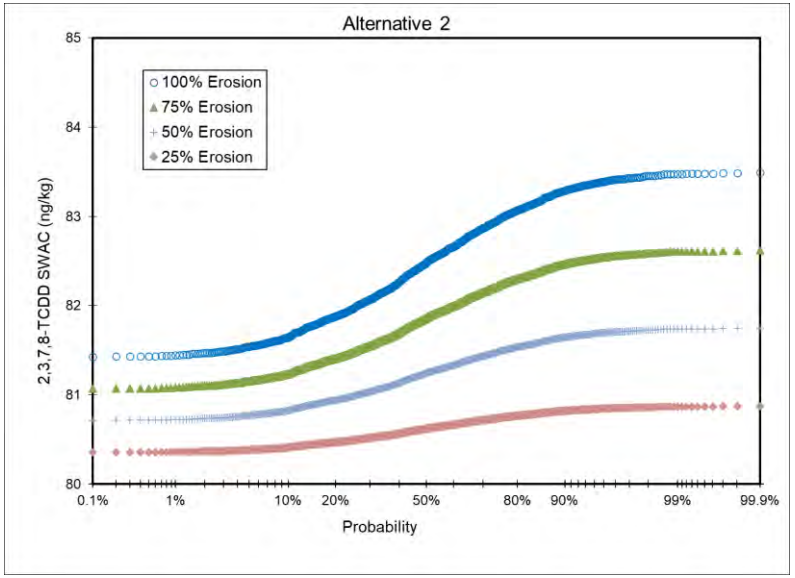
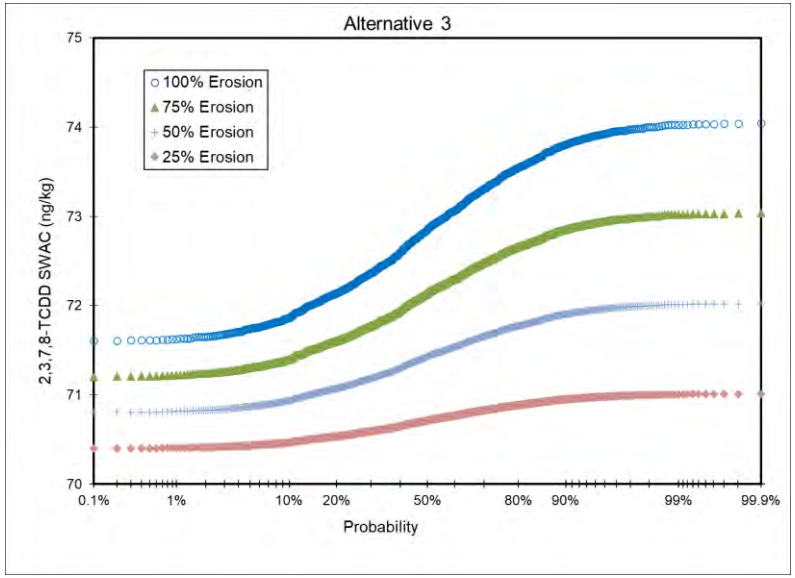
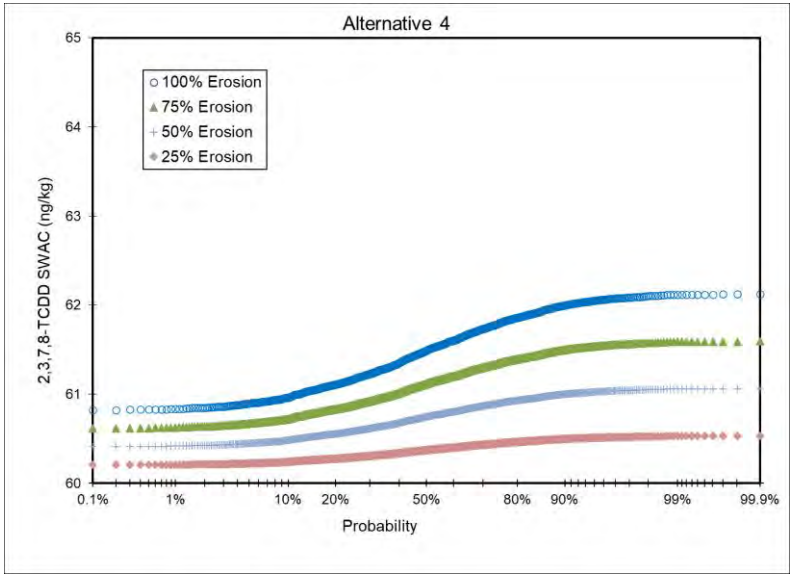
Figure 4-1
Vicinity of the RM 10.9 time-critical removal action (TCRA) Area
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area







Alternative	Total Area of River (AC)	Area of river eroded (AC)	Target Post-Remedy 2,3,7,8-TCDD SWAC (ppt)	Existing Post-Remedy 2,3,7,8-TCDD SWAC (ppt)	Surface RAL (ppt)	Subsurface RAL (ppt)
2	252	2	85	80	260	520
3	252	3	75	70	205	410
4	252	2	65	60	164	328

Notes:

AC: acres

2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin

SWAC: surface-weighted average concentration

ppt: parts per trillion

RAL: remedial action level

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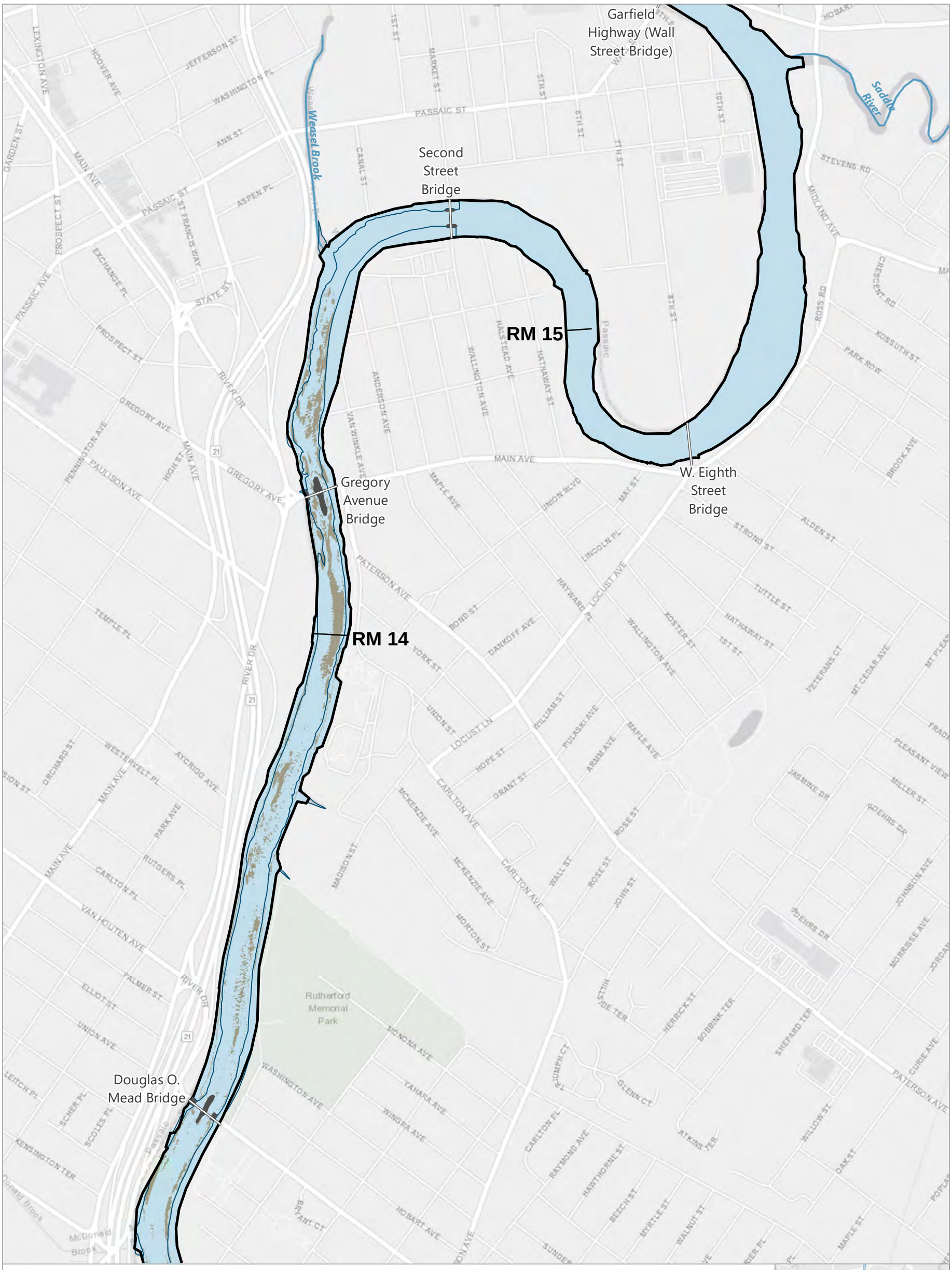
\\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\code\crossplot_acres_concentration_CS_ModelDep_4cs.py

Figure 4-2

Probabilistic Analysis of the Potential Impact of Erosion on the Post-Remedy SWAC

Upper 9 Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- Hybrid Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by RI Erosion and Erosion and Deposition categories where 2007-2012 bathymetric survey data are available, and by areas with model predicted erosion of 15 cm or more during any of the 2010 and 2011 high flow events where bathymetric survey data are unavailable.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.

0 1,000
Feet

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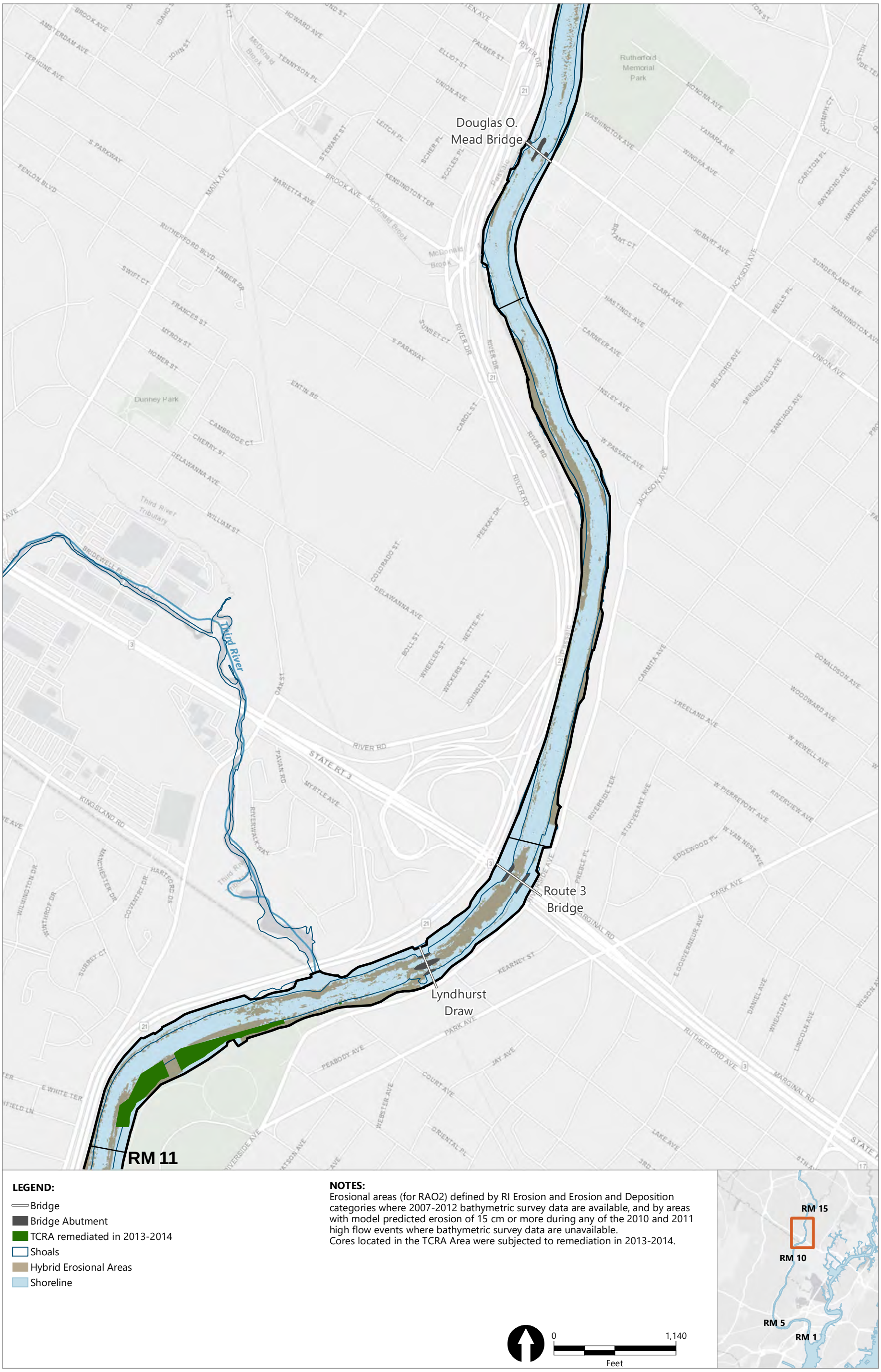
Figure 4-3a
Erosional Areas Used in Remedial Footprint Delineation for the "Desktop Study"
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



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Filepath: H:\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\May2020\Figure_4-3_Erosional_Areas_Desktop_Study.mxd

Figure 4-3b

Erosional Areas Used in Remedial Footprint Delineation for the "Desktop Study"

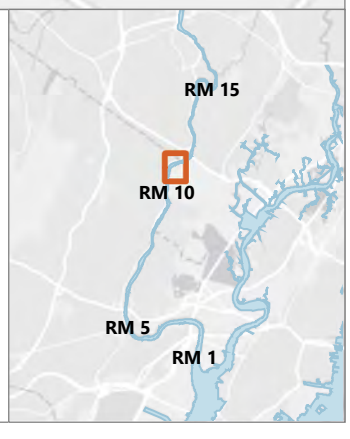
Upper 9 Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- Hybrid Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by RI Erosion and Erosion and Deposition categories where 2007-2012 bathymetric survey data are available, and by areas with model predicted erosion of 15 cm or more during any of the 2010 and 2011 high flow events where bathymetric survey data are unavailable.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.



0 540
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Figure 4-3c
Erosional Areas Used in Remedial Footprint Delineation for the "Desktop Study"
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

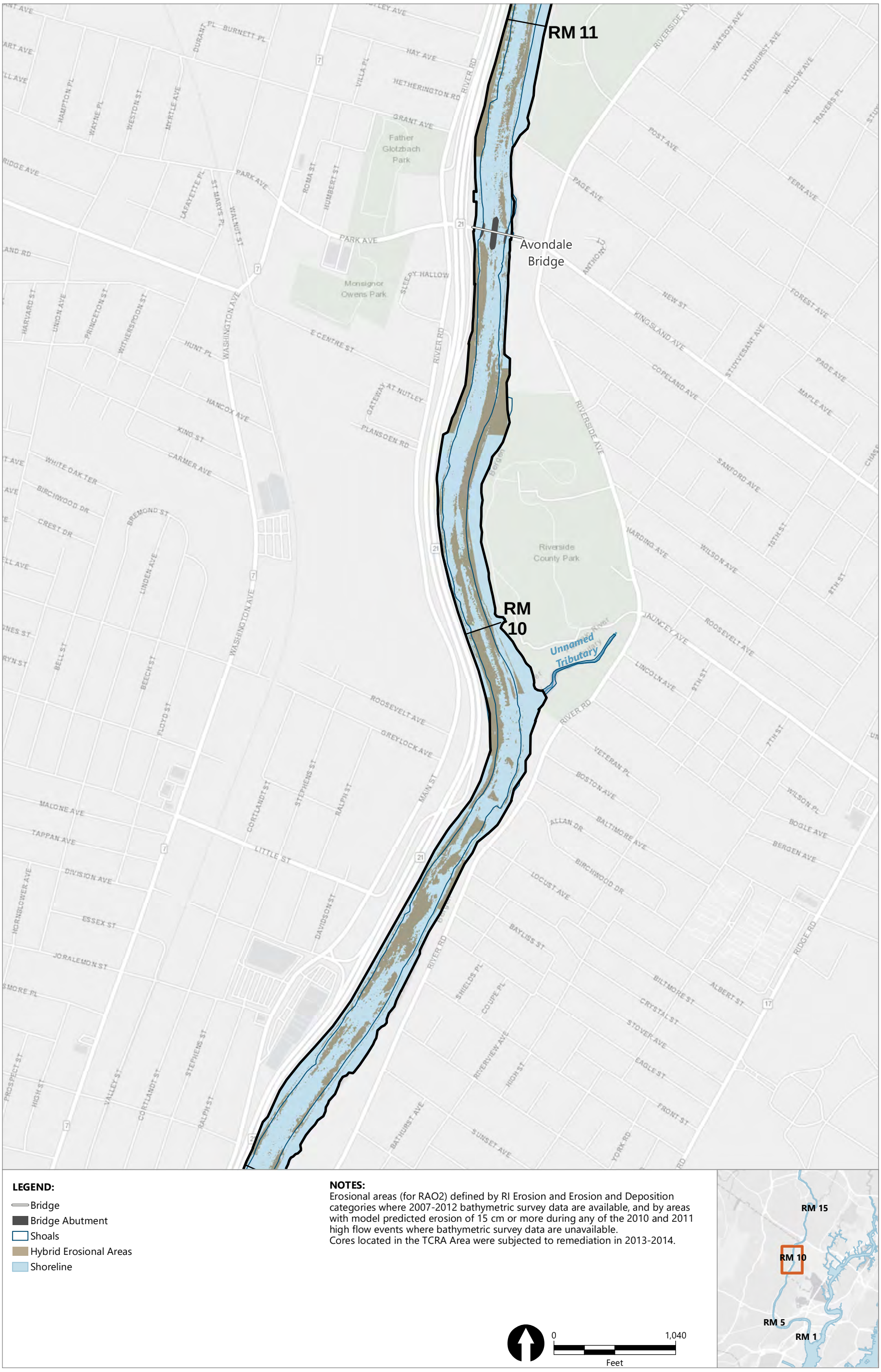

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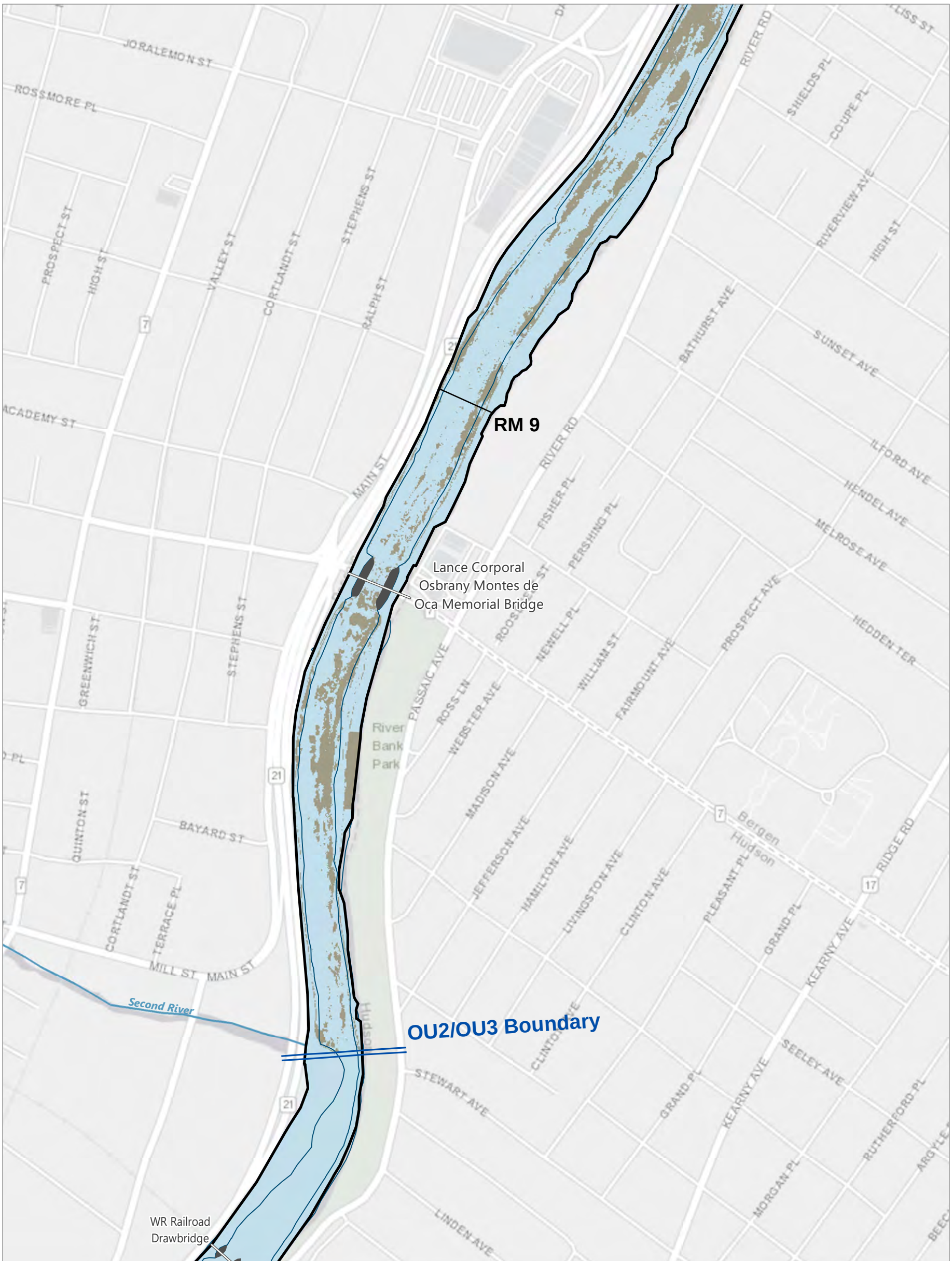
Figure 4-3d

Erosional Areas Used in Remedial Footprint Delineation for the "Desktop Study"

Upper 9 Mile Source Control Interim Remedy Feasibility Study

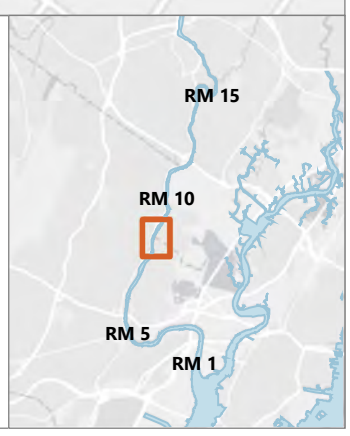
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- Hybrid Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by RI Erosion and Erosion and Deposition categories where 2007-2012 bathymetric survey data are available, and by areas with model predicted erosion of 15 cm or more during any of the 2010 and 2011 high flow events where bathymetric survey data are unavailable.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.



0 700
Feet

Publish Date: 2020/05/13, 5:00 PM | User: mmathew
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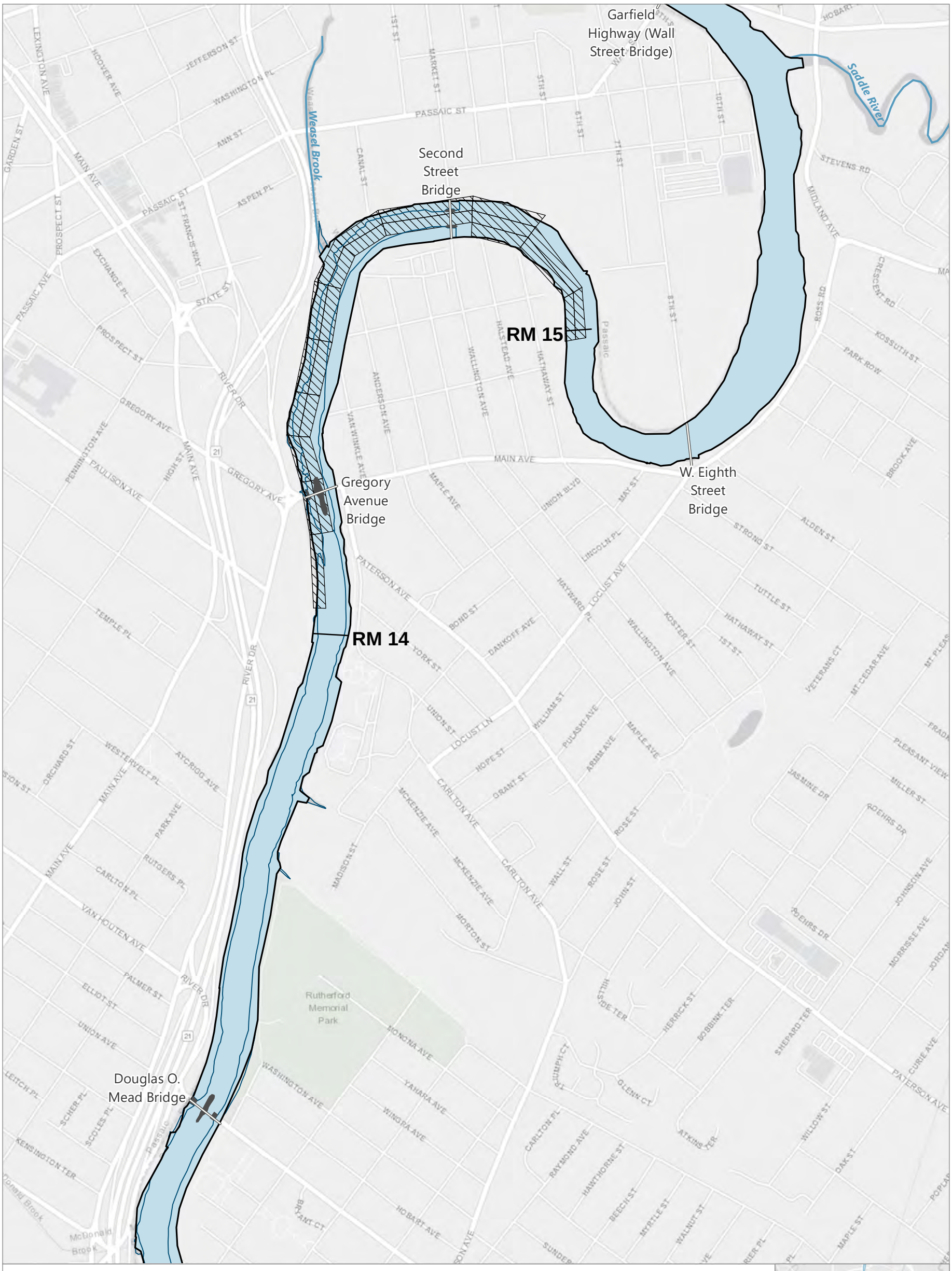
Figure 4-3e
Erosional Areas Used in Remedial Footprint Delineation for the "Desktop Study"
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- Model Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.

0 1,060
Feet

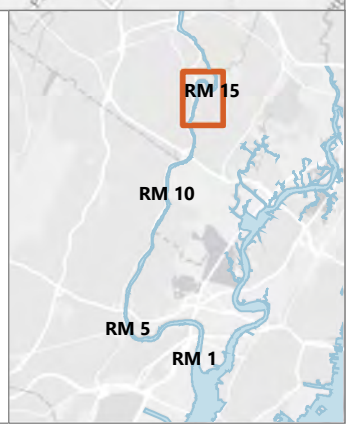


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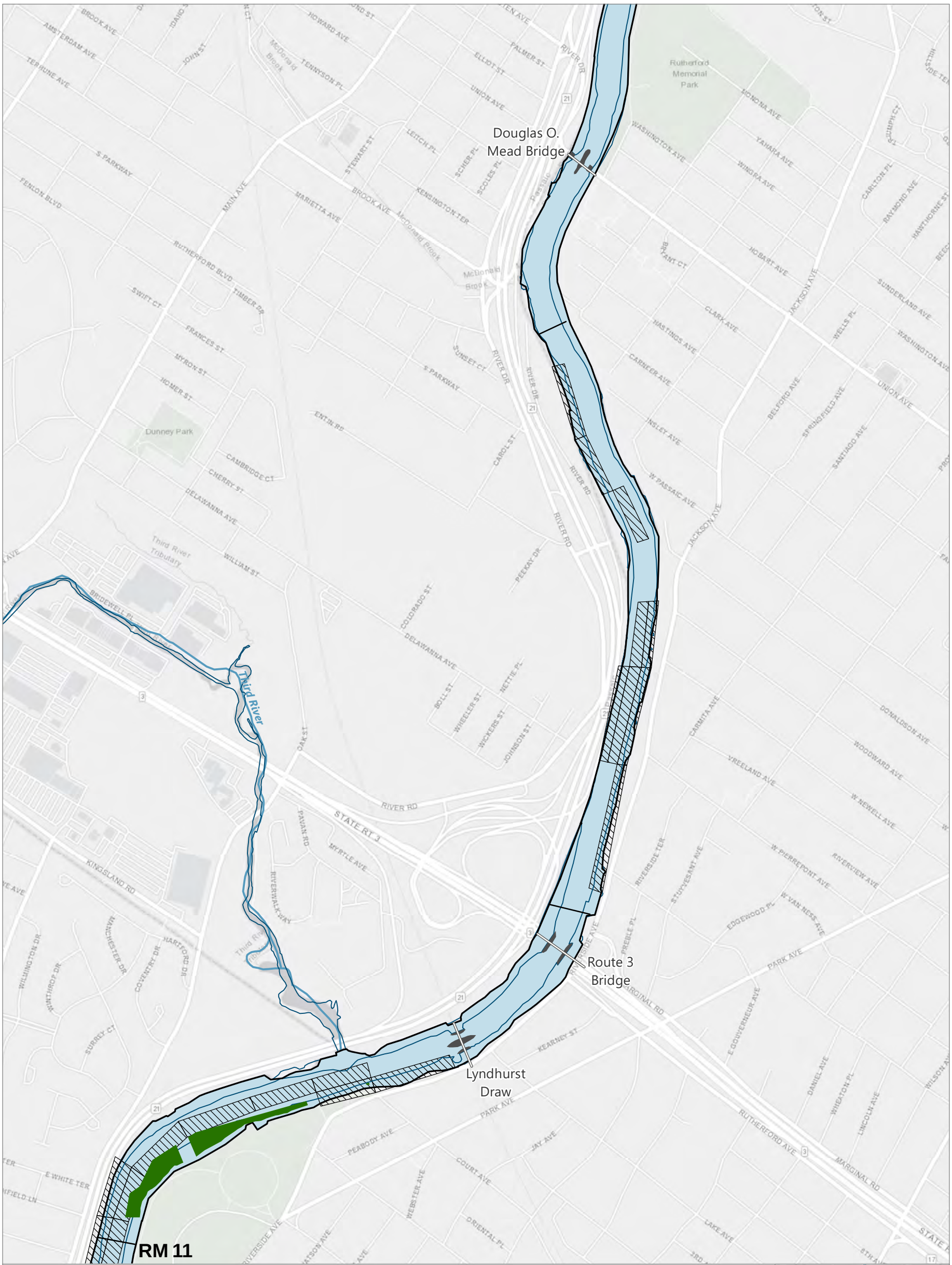
Figure 4-4a
Erosional Areas Used in Remedial Footprint Delineation for the Model Projections
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- Model Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.

0 1,200
Feet

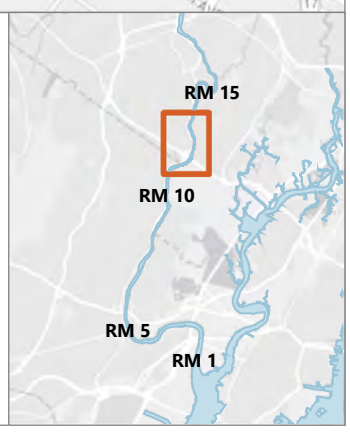


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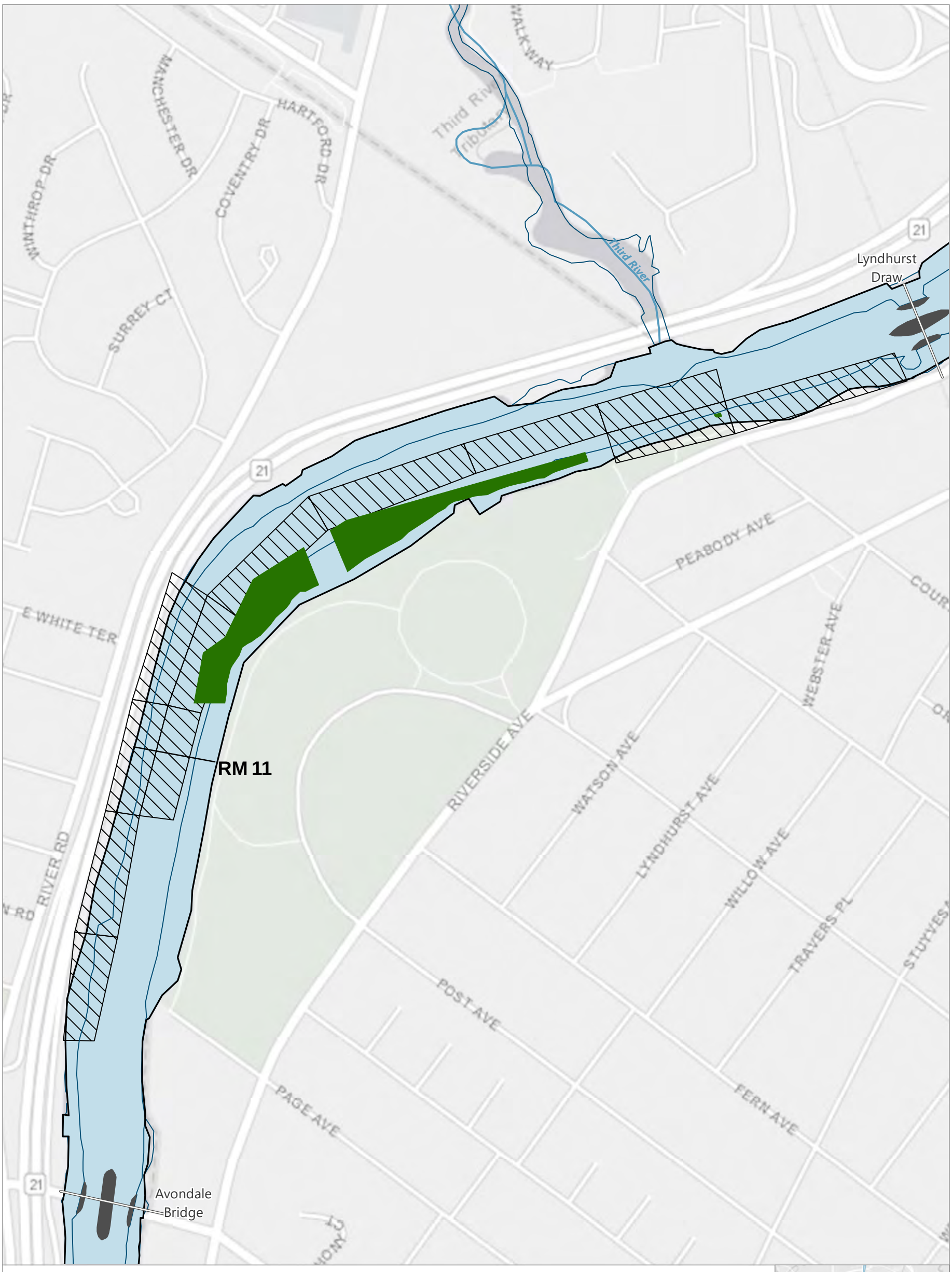
Figure 4-4b
Erosional Areas Used in Remedial Footprint Delineation for the Model Projections
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- Model Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.

0 560
Feet

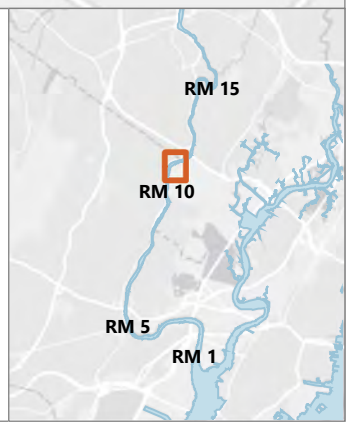


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Figure 4-4c
Erosional Areas Used in Remedial Footprint Delineation for the Model Projections
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

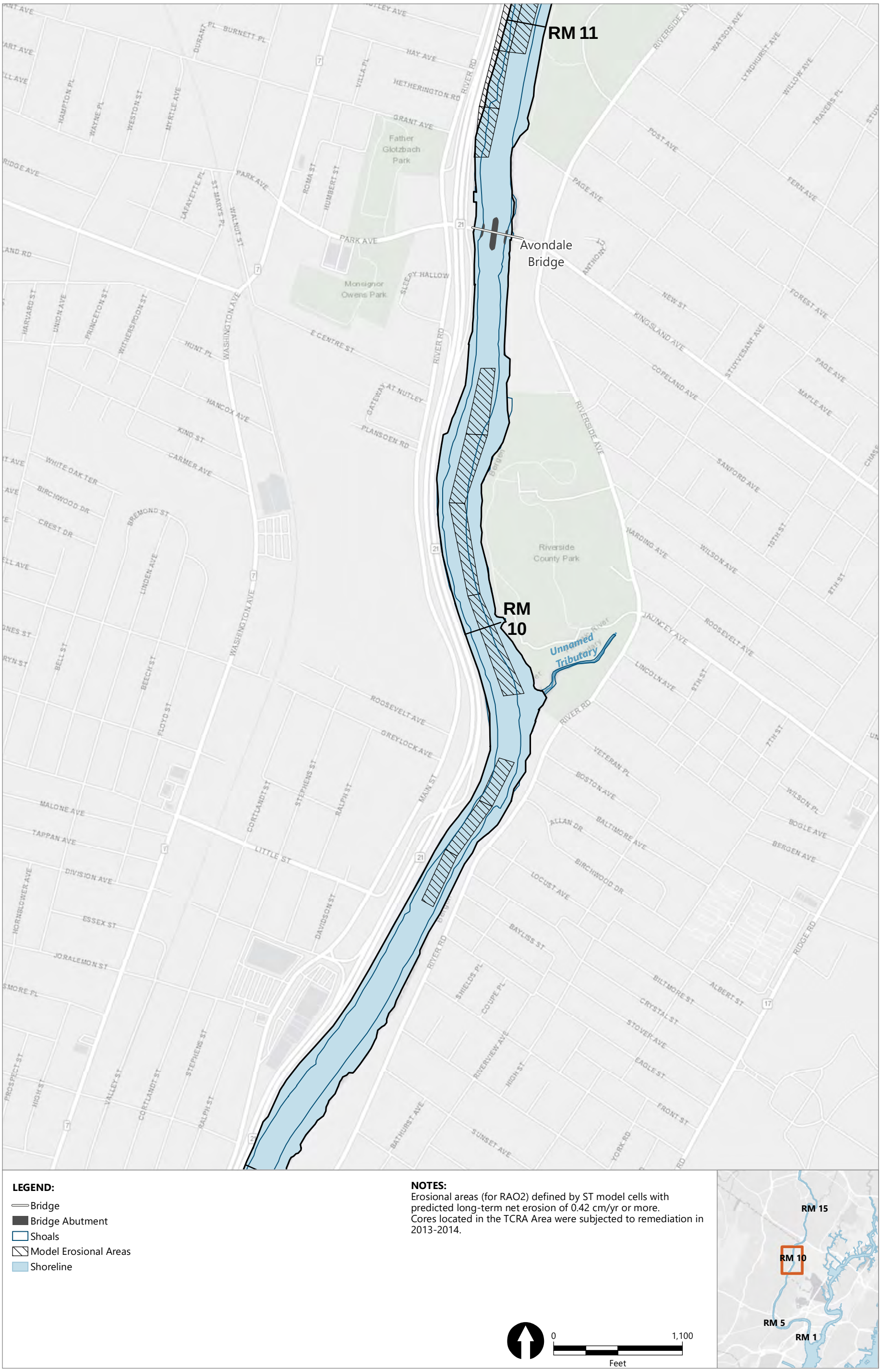

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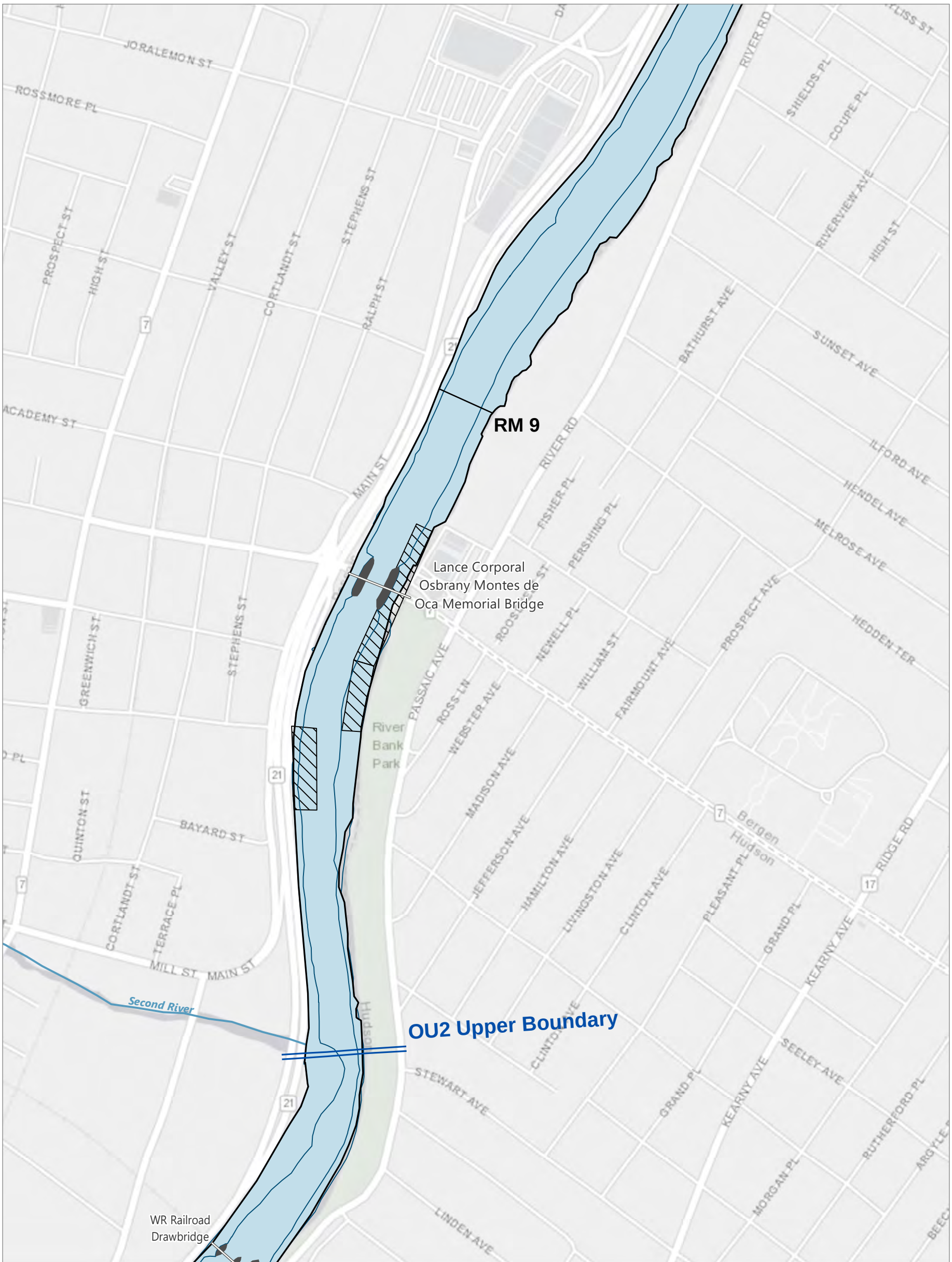
Figure 4-4d

Erosional Areas Used in Remedial Footprint Delineation for the Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- Model Erosional Areas
- Shoreline

NOTES:
Erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
Cores located in the TCRA Area were subjected to remediation in 2013-2014.

0 750
Feet

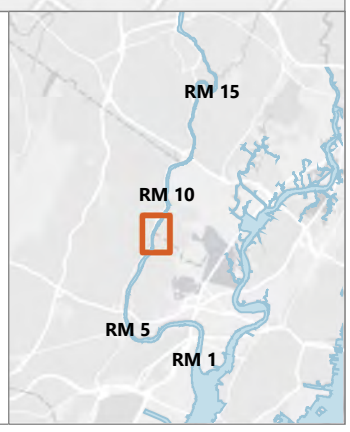


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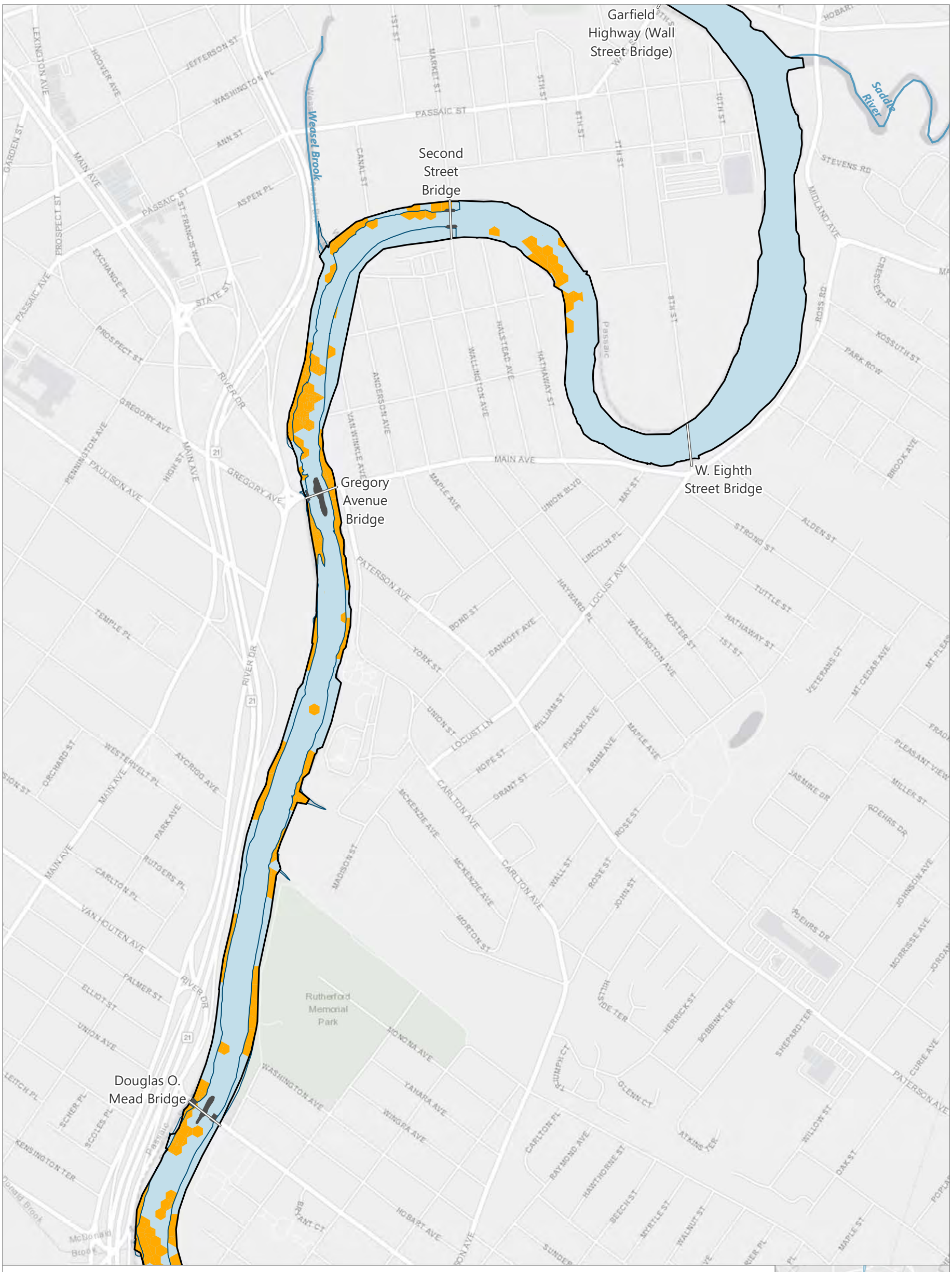
Figure 4-4e
Erosional Areas Used in Remedial Footprint Delineation for the Model Projections
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 85 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 85 ppt SWAC Alternative: 260 ppt / 520 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,060
Feet

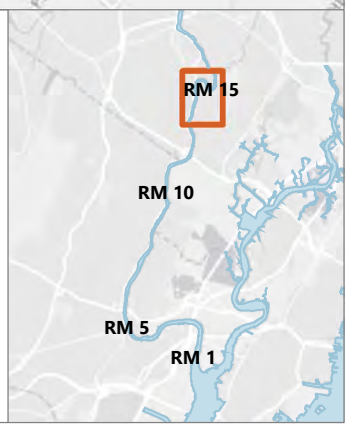


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Figure 5-1a

Remedial Footprint for the 85 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 85 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 85 ppt SWAC Alternative: 260 ppt / 520 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,200
Feet

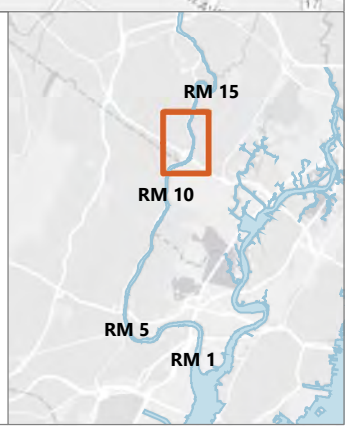

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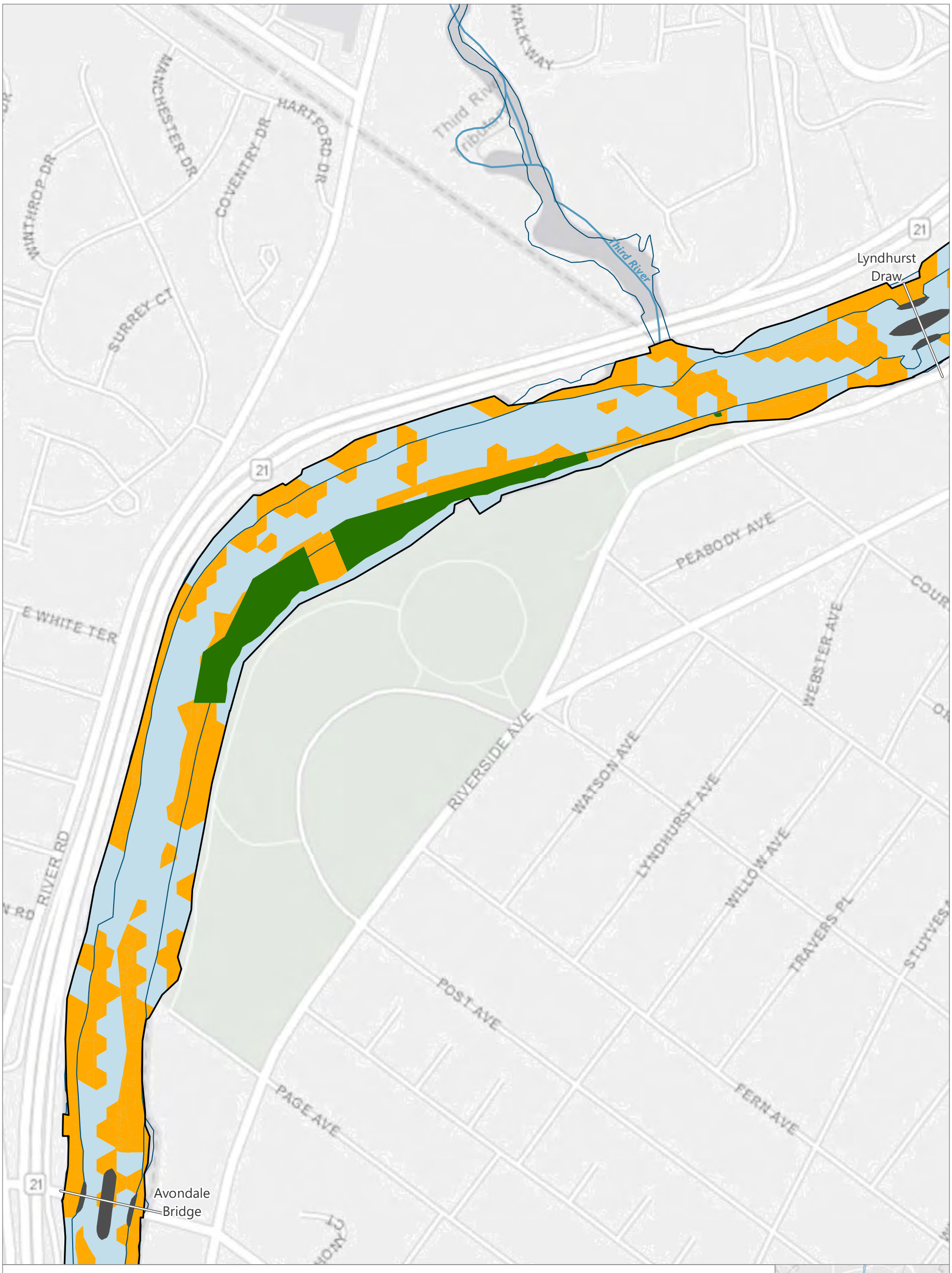
Figure 5-1b

Remedial Footprint for the 85 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 85 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 85 ppt SWAC Alternative: 260 ppt / 520 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 560
Feet

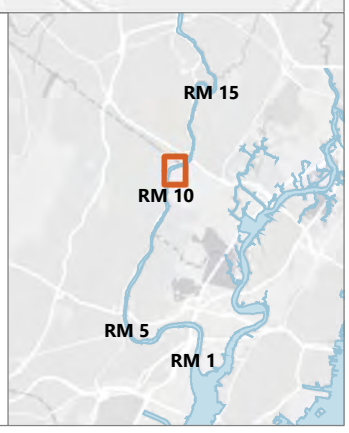


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Figure 5-1c

Remedial Footprint for the 85 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

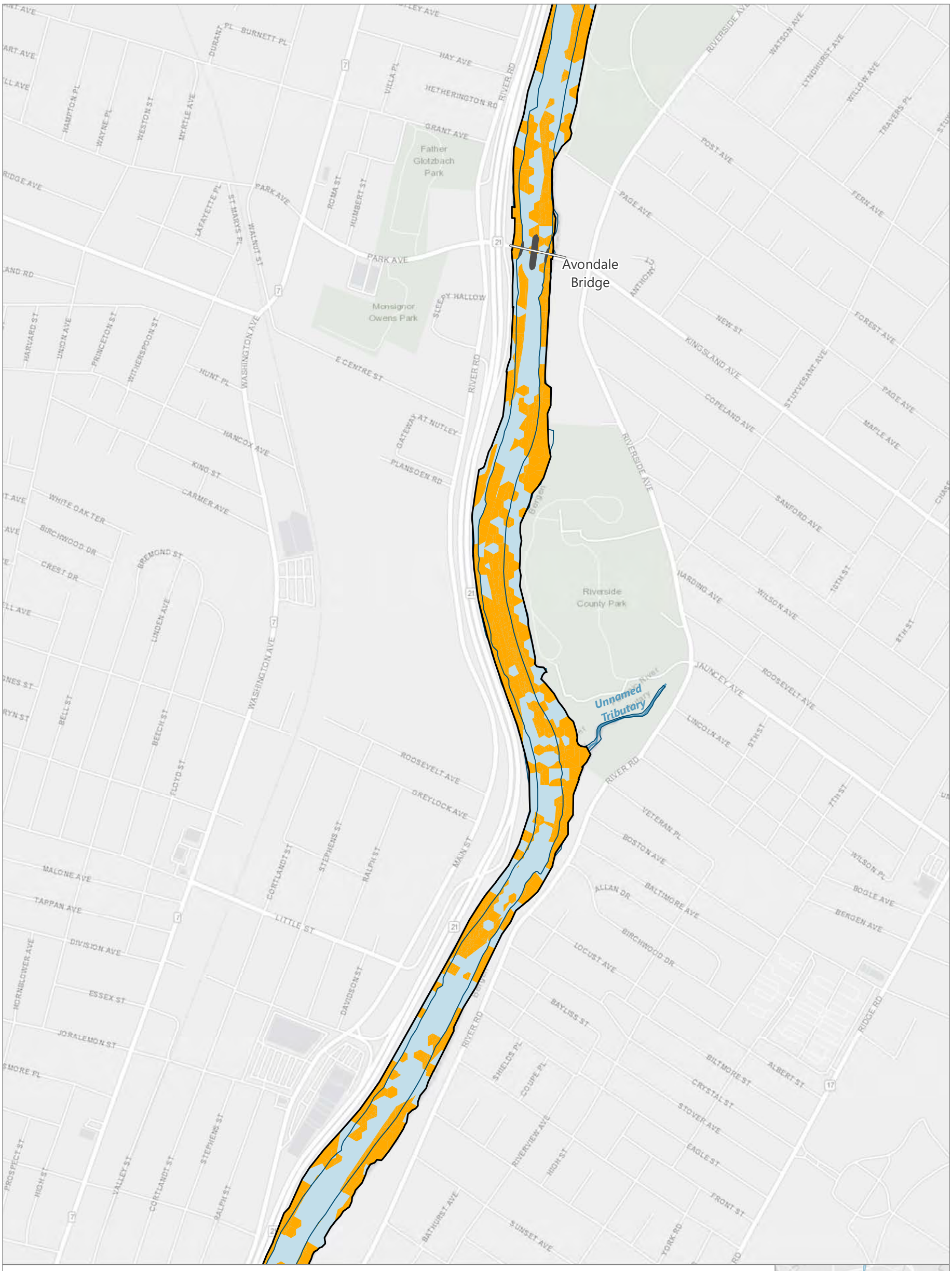

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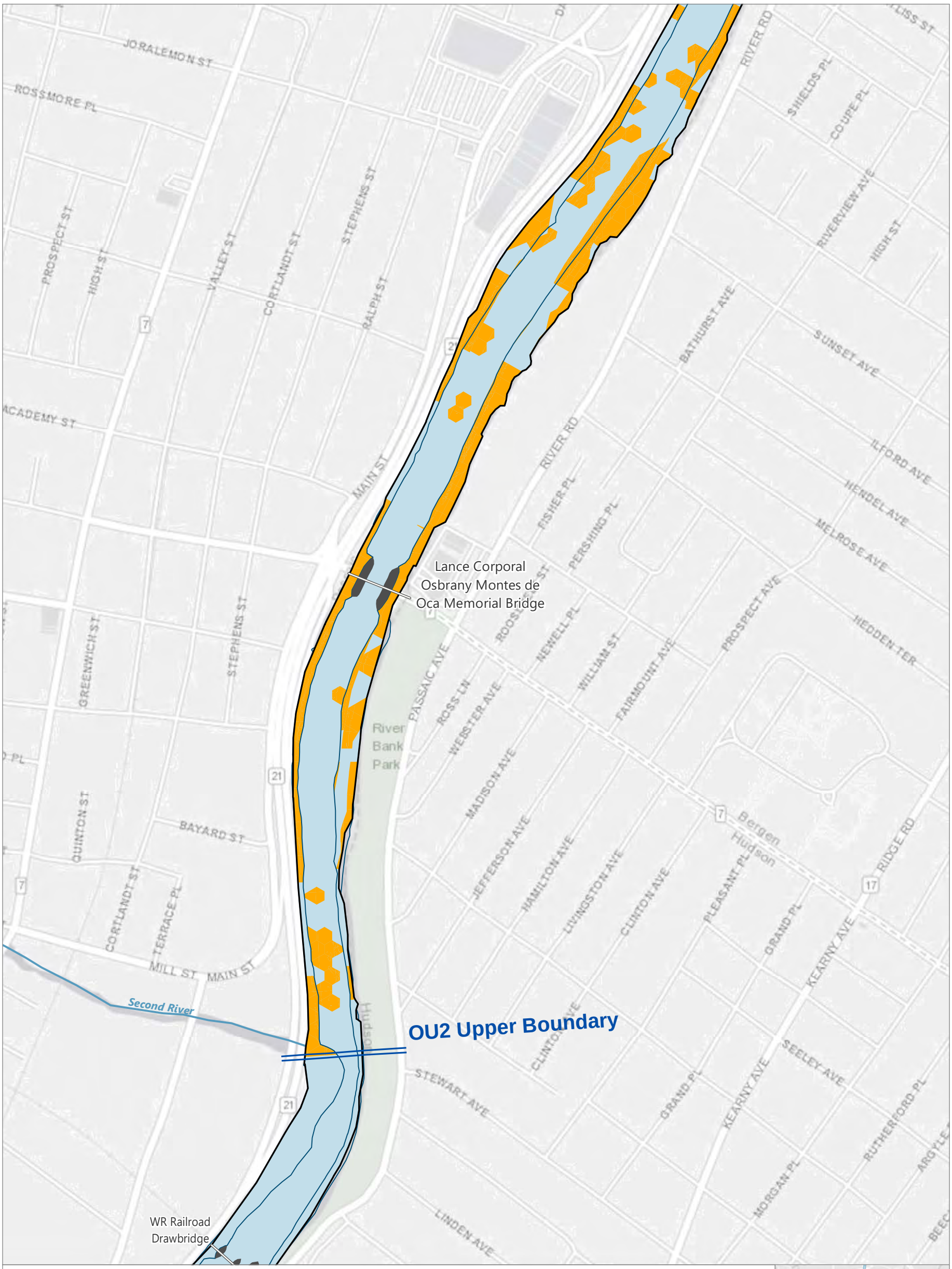
Figure 5-1d

Remedial Footprint for the 85 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 85 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 85 ppt SWAC Alternative: 260 ppt / 520 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 740
Feet

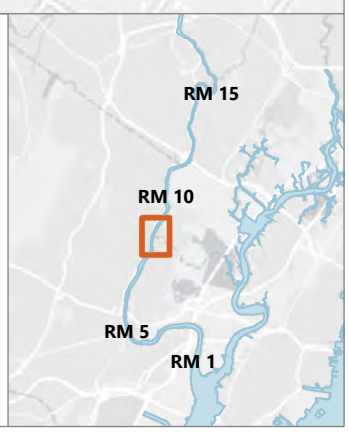


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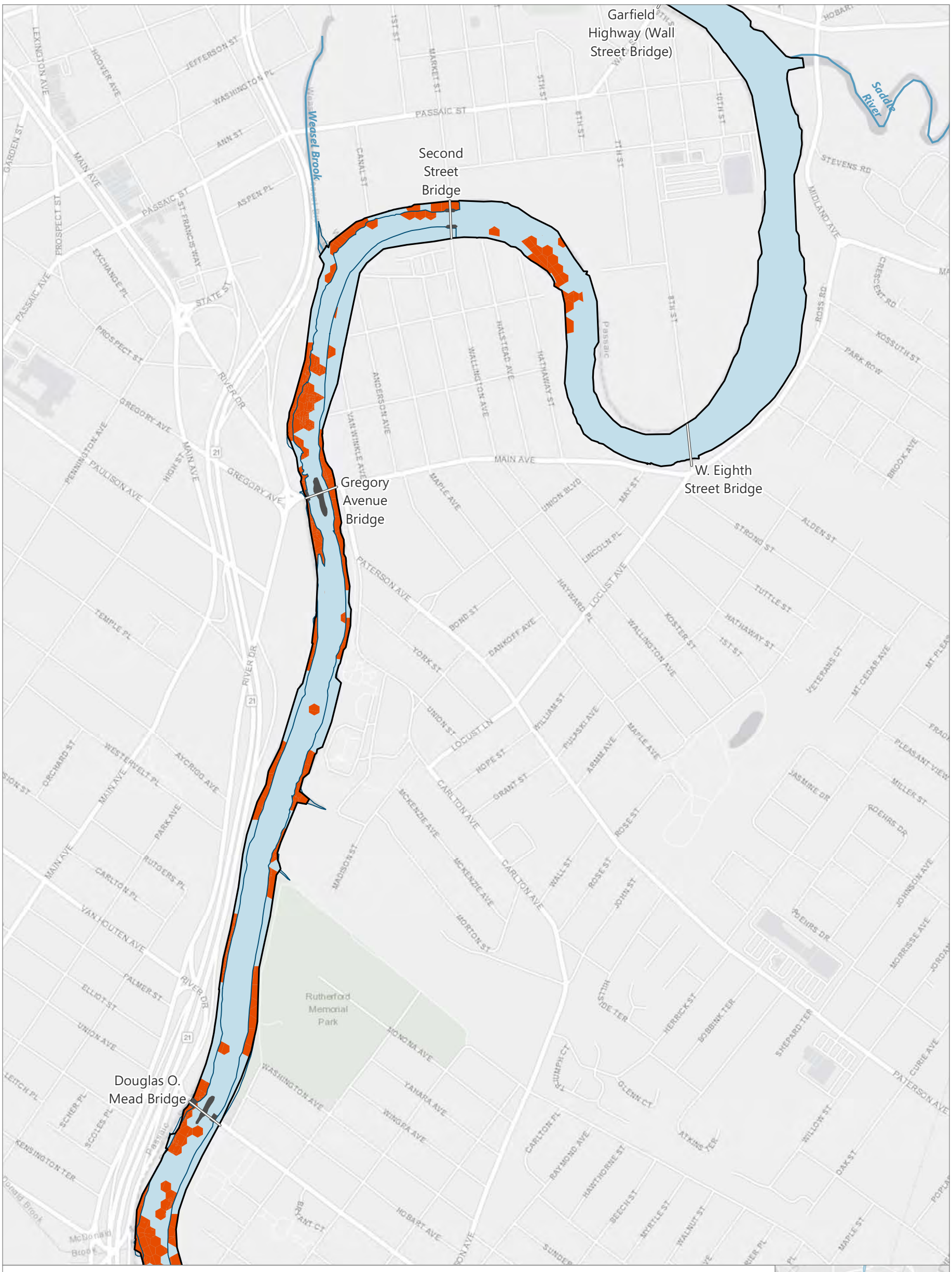
Figure 5-1e

Remedial Footprint for the 85 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 75 ppt SWAC Alternative: 205 ppt / 410 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,060
Feet

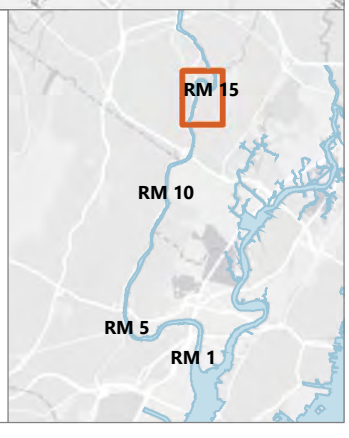


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Figure 5-2a

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 75 ppt SWAC Alternative: 205 ppt / 410 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,200
Feet

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Figure 5-2b

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 75 ppt SWAC Alternative: 205 ppt / 410 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 560
Feet

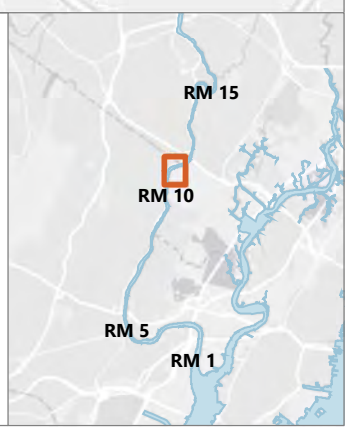

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Figure 5-2c

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

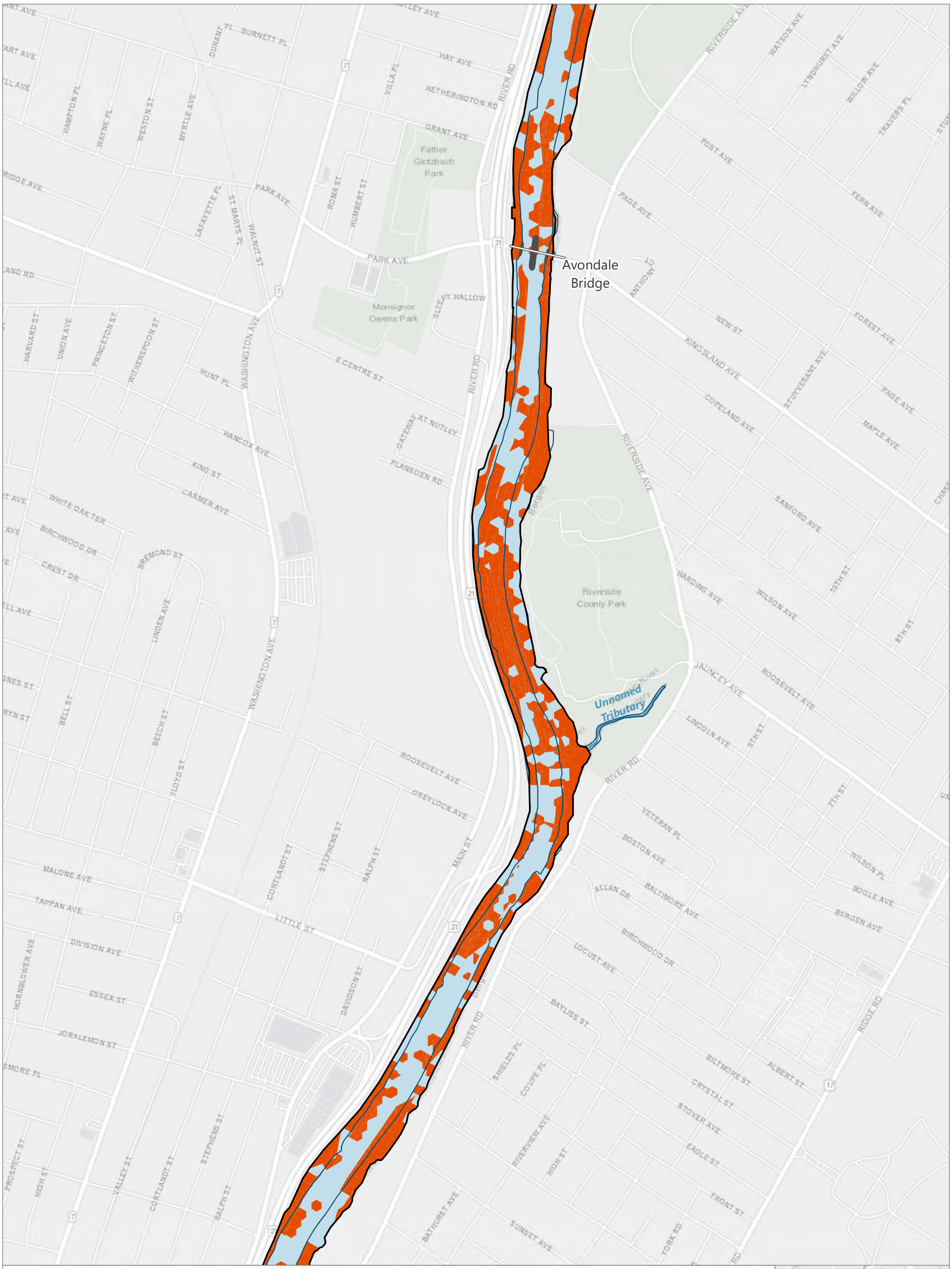

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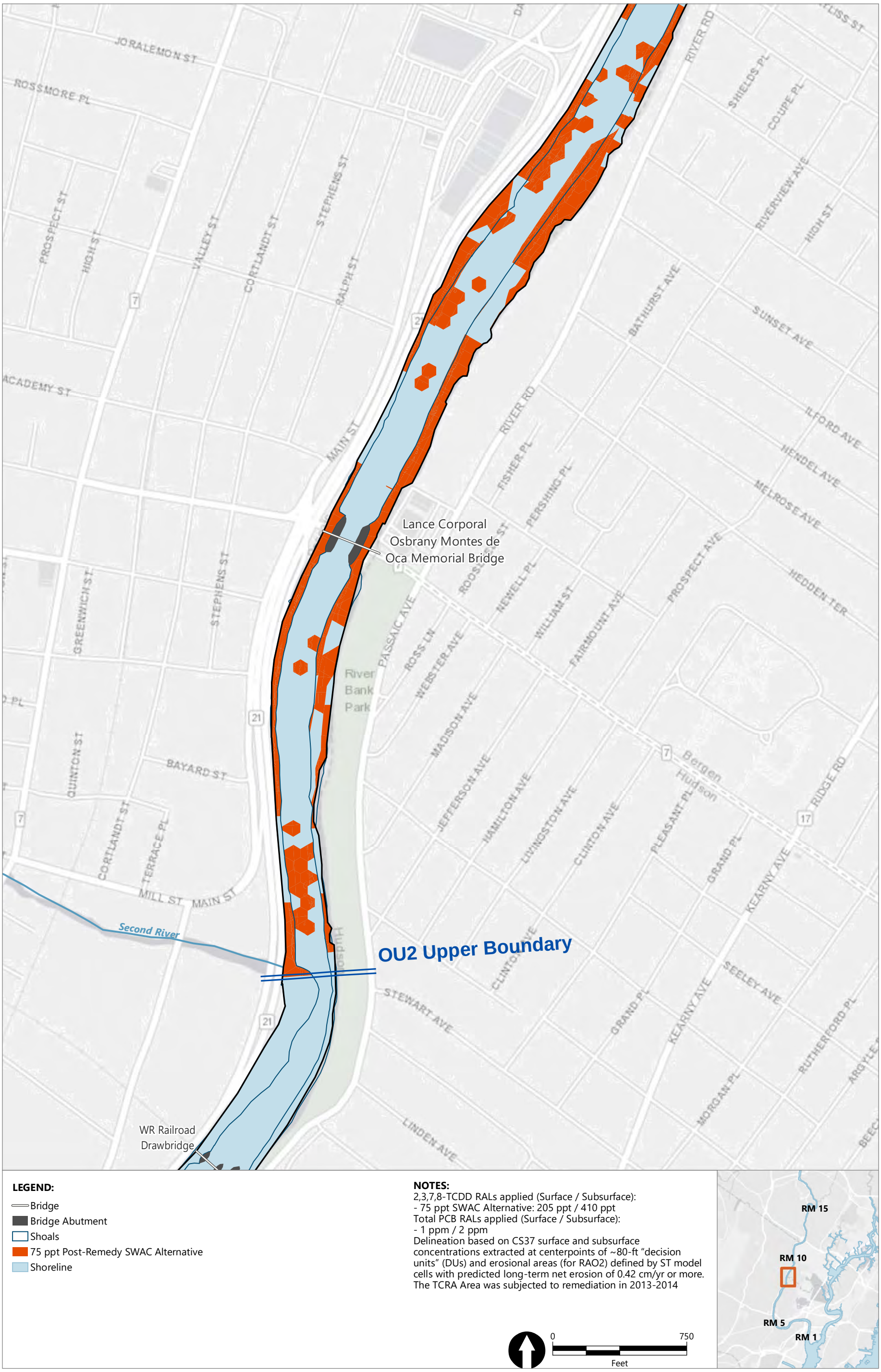
Figure 5-2d

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



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Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-2_CS37_75ppt_Model.mxd

Figure 5-2e

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

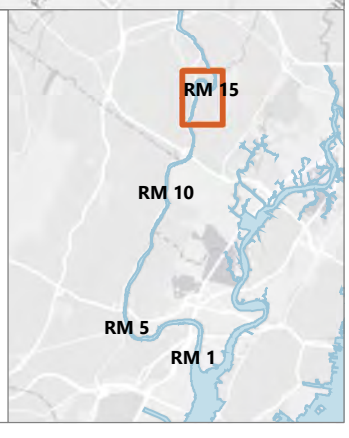
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 65 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 65 ppt SWAC Alternative: 164 ppt / 328 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,060
Feet



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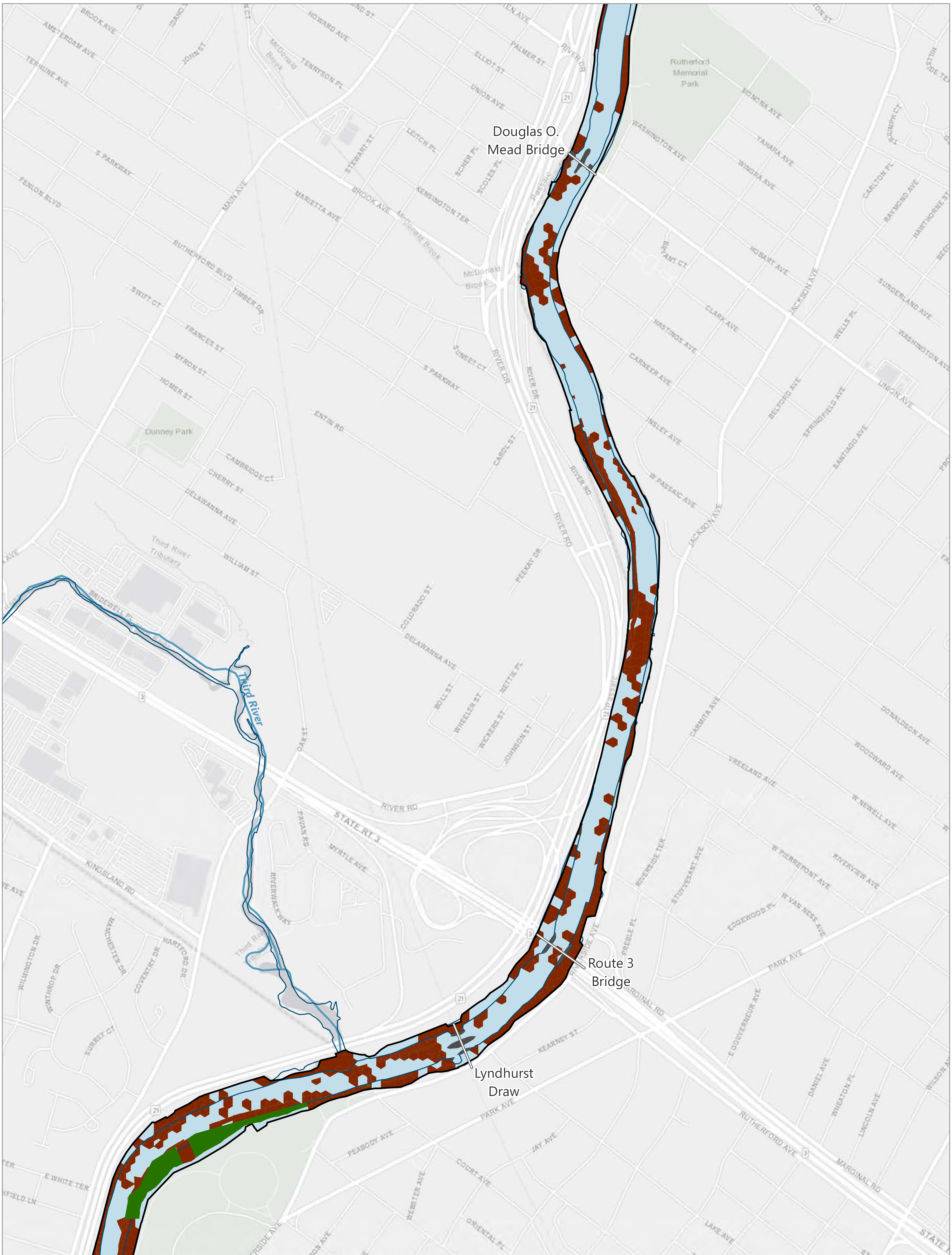
Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-3_CS37_65ppt_Model.mxd

Figure 5-3a

Remedial Footprint for the 65 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

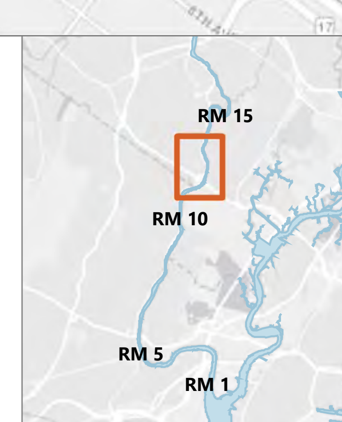


LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 65 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 65 ppt SWAC Alternative: 164 ppt / 328 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 — 1,200
Feet



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Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-3_CS37_65ppt_Model.mxd

Figure 5-3b
Remedial Footprint for the 65 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 65 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 65 ppt SWAC Alternative: 164 ppt / 328 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 560
Feet

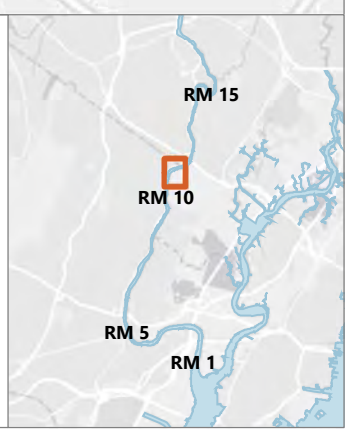

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Figure 5-3c

Remedial Footprint for the 65 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

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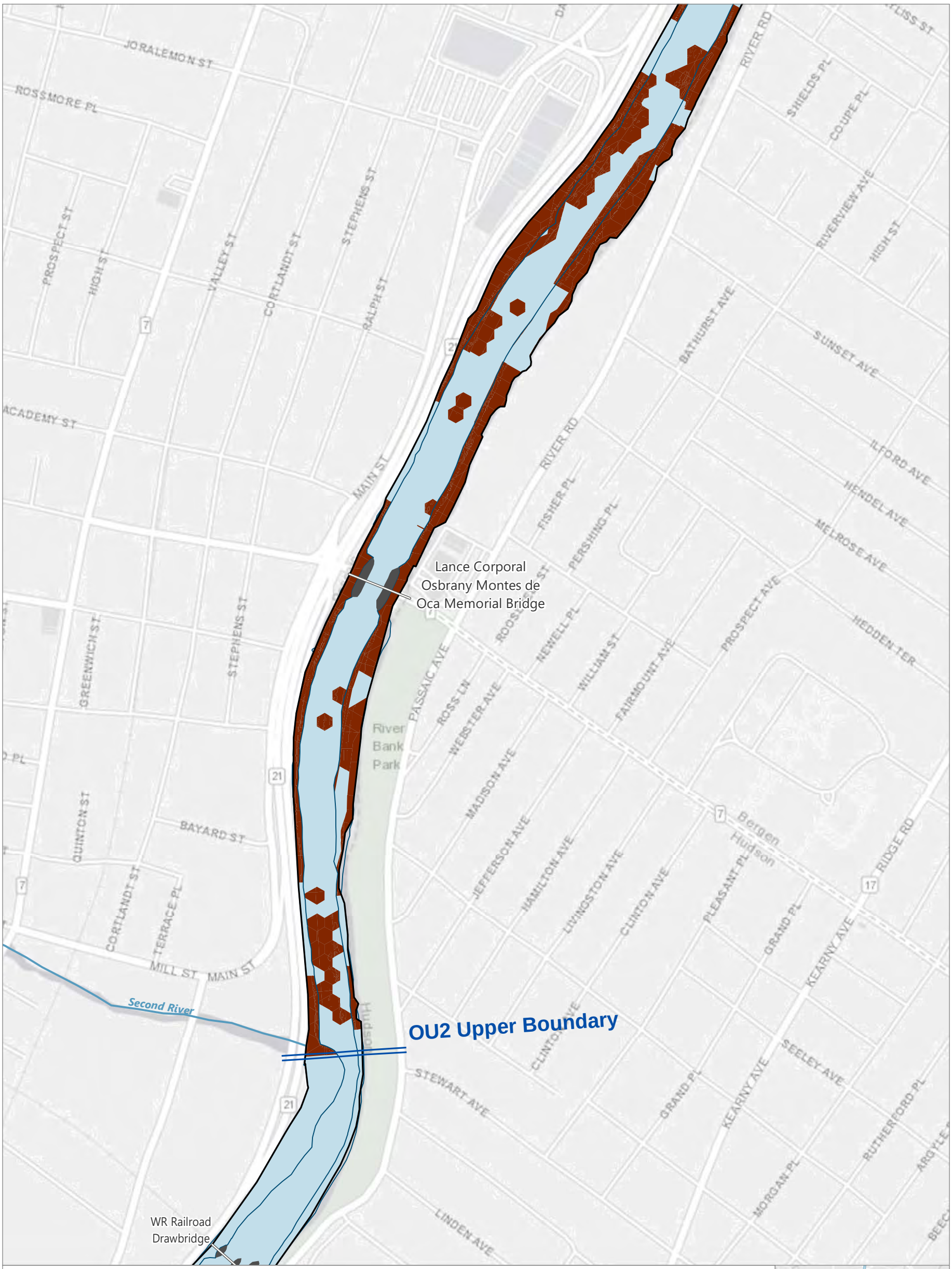
Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-3_CS37_65ppt_Model.mxd

Figure 5-3d

Remedial Footprint for the 65 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

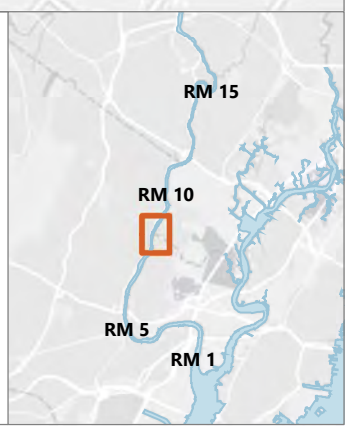


LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 65 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 65 ppt SWAC Alternative: 164 ppt / 328 ppt
Total PCB RALs applied (Surface / Subsurface):
- 1 ppm / 2 ppm
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 750
Feet



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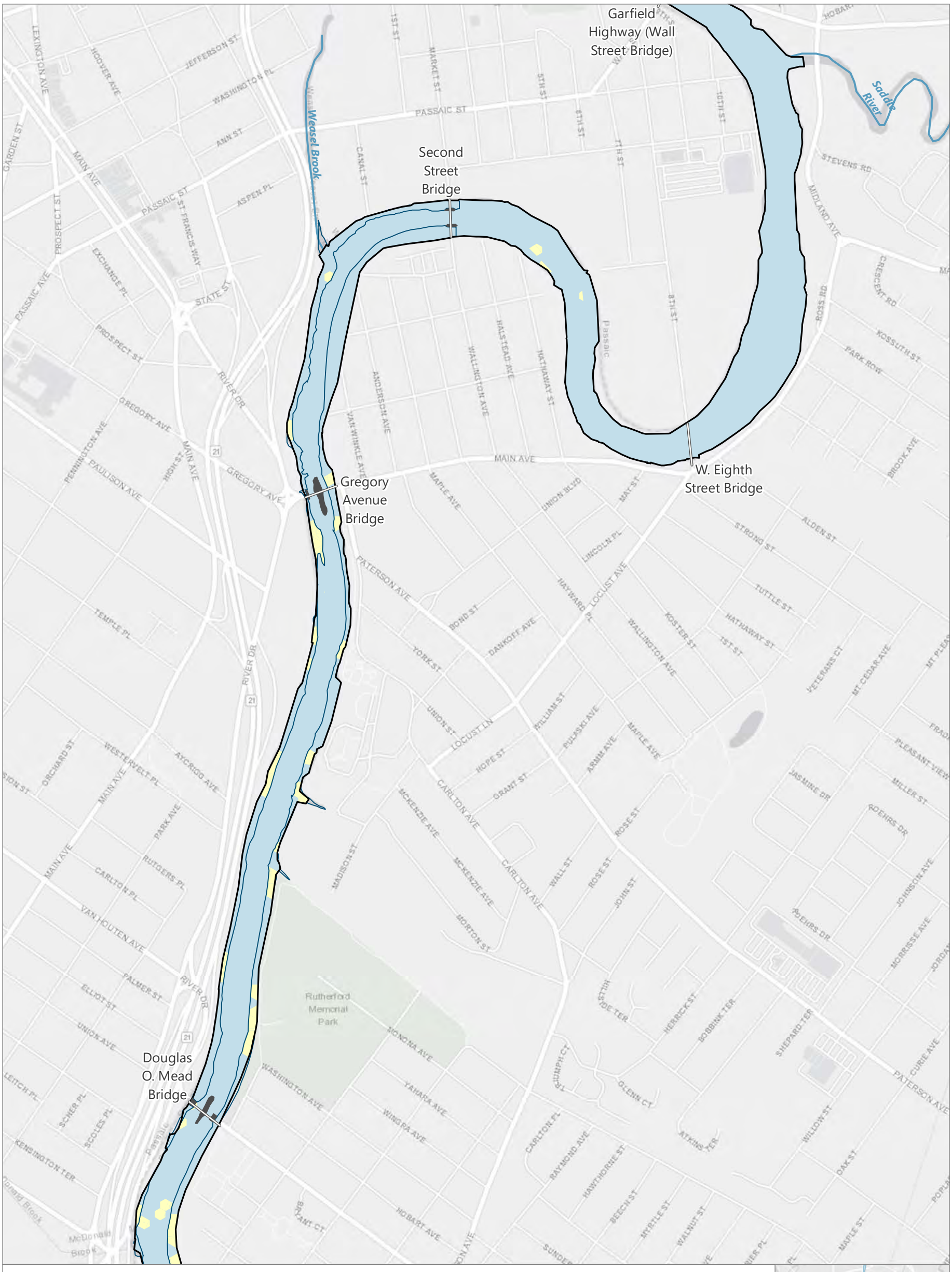
Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-3_CS37_65ppt_Model.mxd

Figure 5-3e

Remedial Footprint for the 65 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 125 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 125 ppt SWAC Alternative: 346 ppt / 692 ppt
No Total PCB RALs were applied.
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,060
Feet

RM 15
RM 10
RM 5
RM 1

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Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-4_CS37_125ppt_Model.mxd

Figure 5-4a

Remedial Footprint for the 125 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 125 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 125 ppt SWAC Alternative: 346 ppt / 692 ppt
No Total PCB RALs were applied.
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,200
Feet

RM 15
RM 10
RM 5
RM 1

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Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-4_CS37_125ppt_Model.mxd

Figure 5-4b

Remedial Footprint for the 125 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

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Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-4_CS37_125ppt_Model.mxd

Figure 5-4c

Remedial Footprint for the 125 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 125 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 125 ppt SWAC Alternative: 346 ppt / 692 ppt
No Total PCB RALs were applied.
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,100
Feet

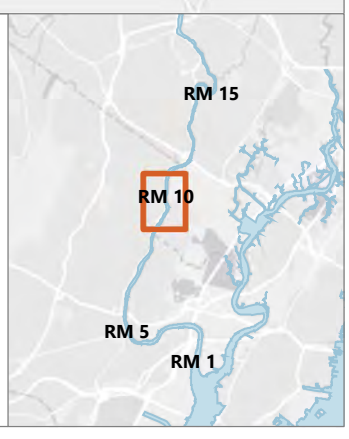

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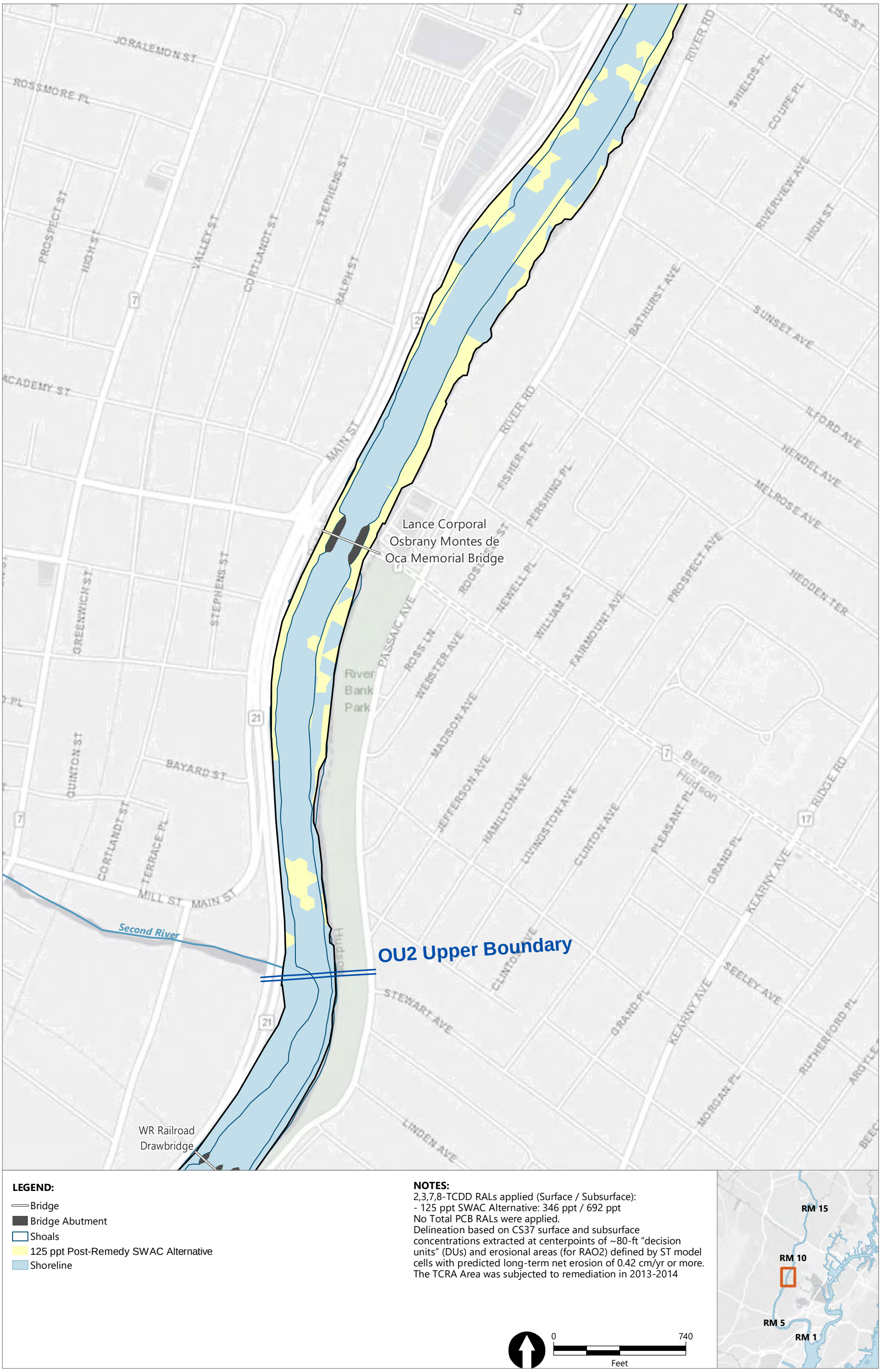
Figure 5-4d

Remedial Footprint for the 125 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 125 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface):
- 125 ppt SWAC Alternative: 346 ppt / 692 ppt
No Total PCB RALs were applied.
Delineation based on CS37 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 740
Feet

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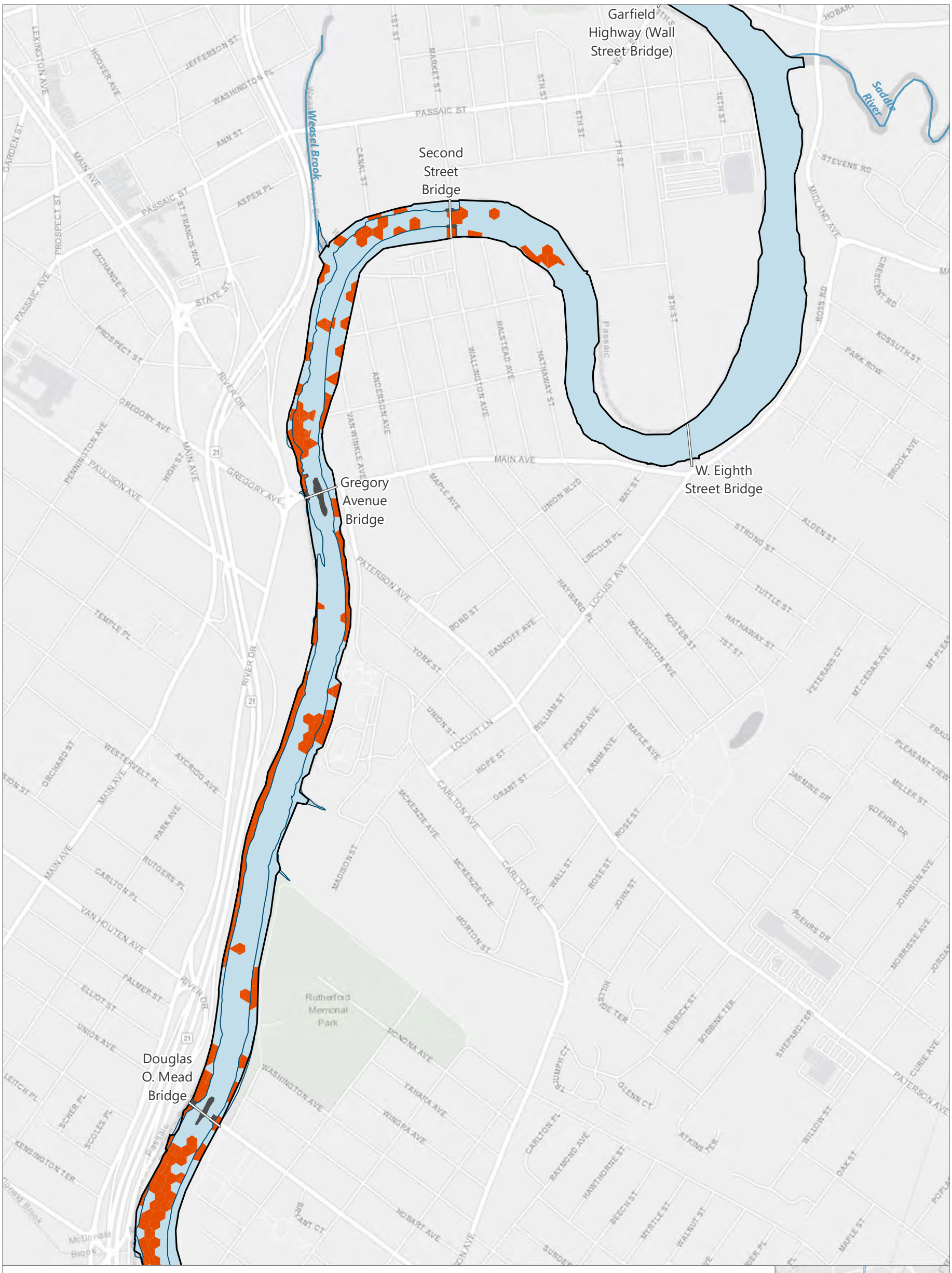
Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-4_CS37_125ppt_Model.mxd

Figure 5-4e

Remedial Footprint for the 125 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 37 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface): 191 ppt / 382 ppt
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm
Delineation based on CS57 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,060
Feet

RM 15
RM 10
RM 5
RM 1

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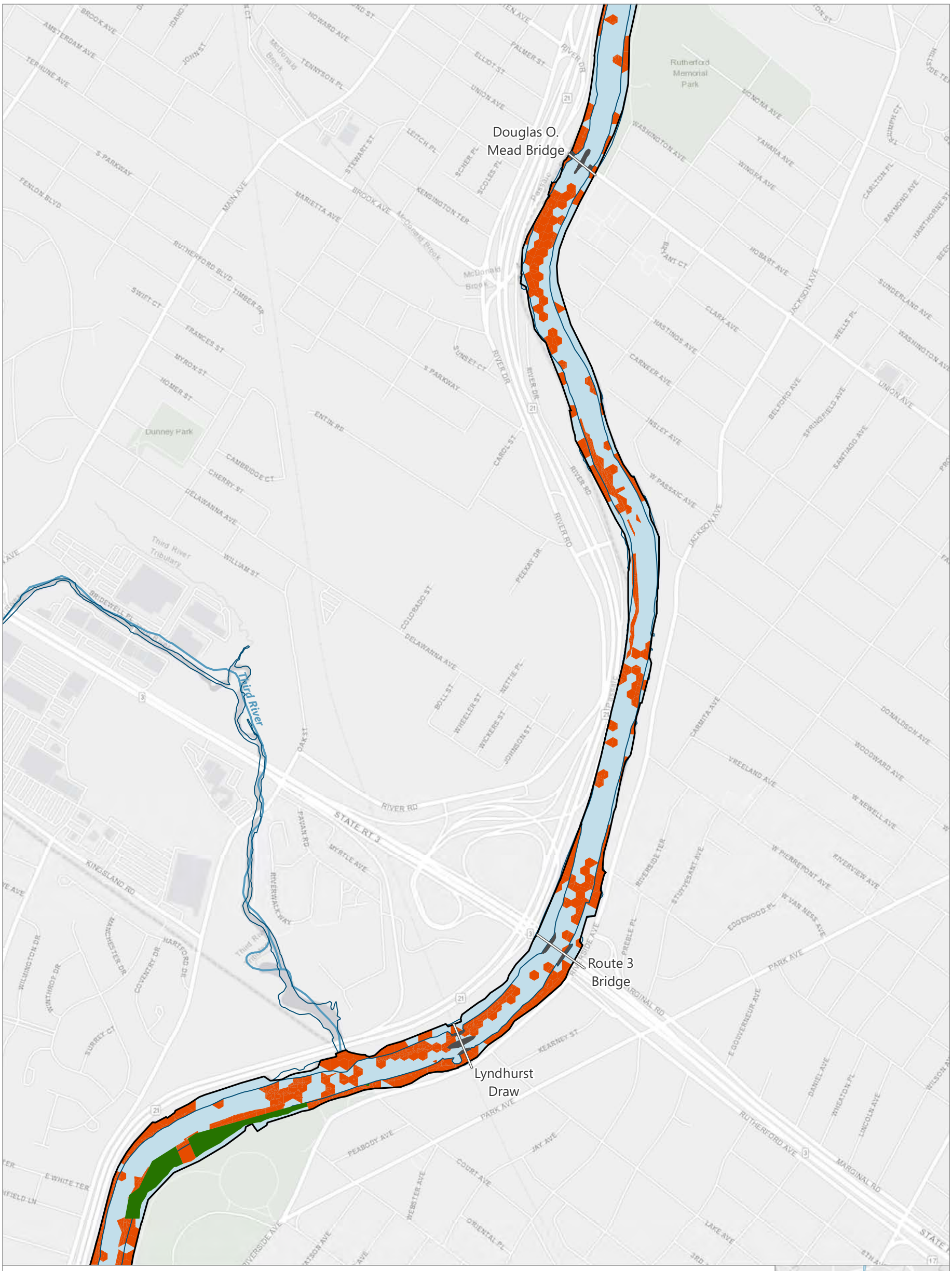
Figure 5-5a

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 57 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

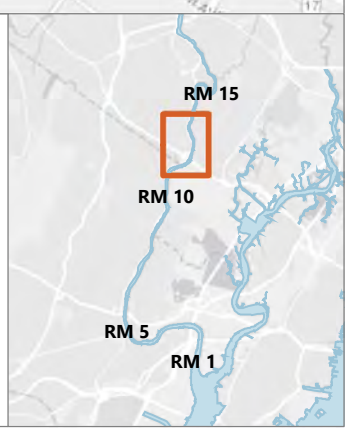


LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface): 191 ppt / 382 ppt
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm
Delineation based on CS57 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,200
Feet



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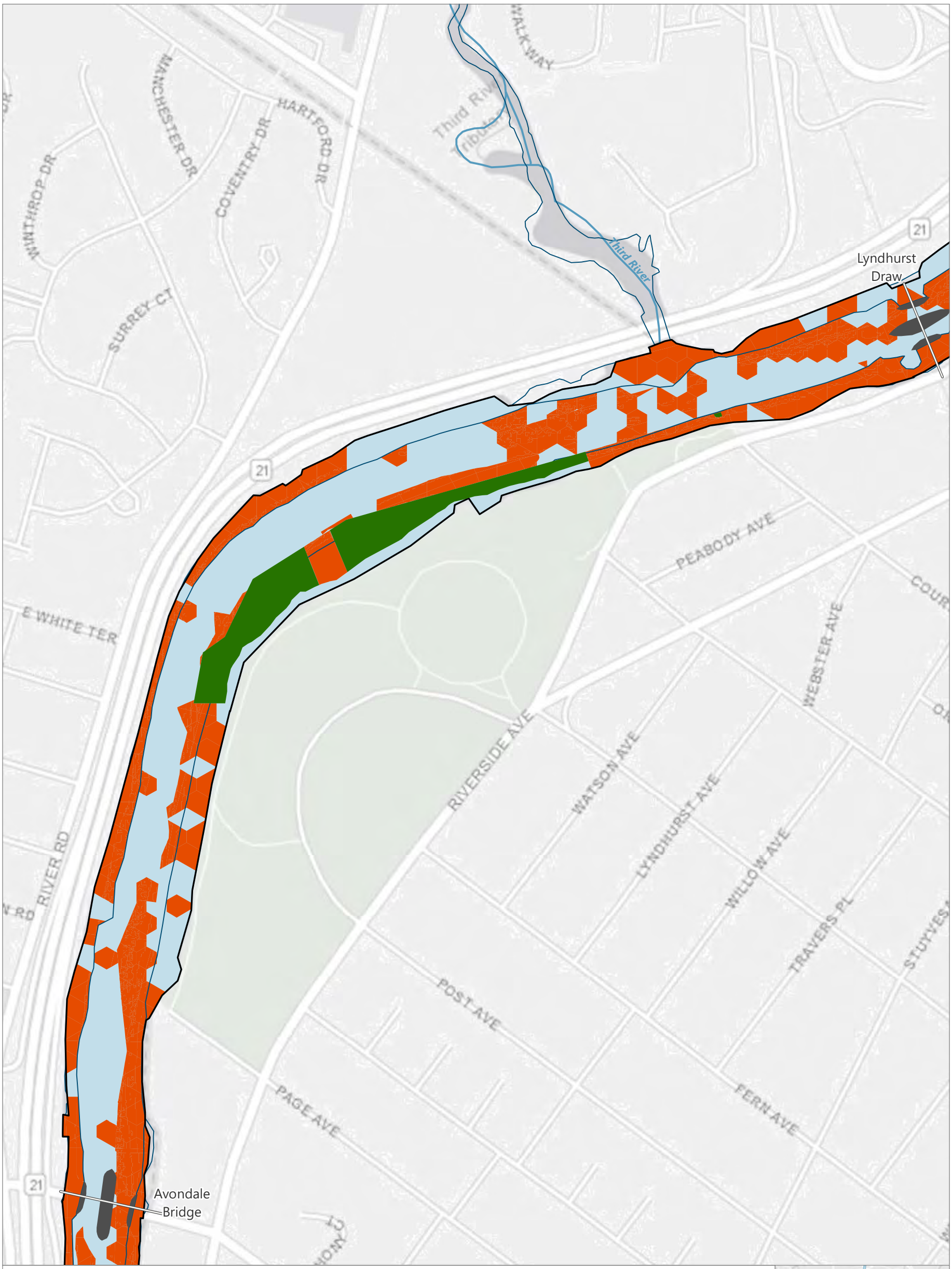
Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-5_CS57_75ppt_Model.mxd

Figure 5-5b

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 57 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

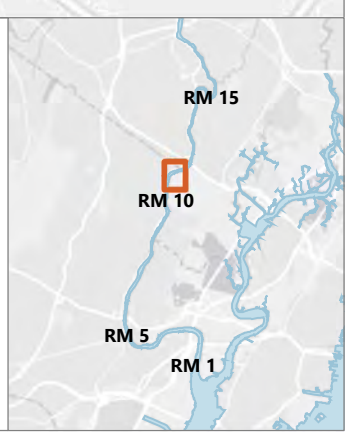


LEGEND:

- Bridge
- Bridge Abutment
- TCRA remediated in 2013-2014
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface): 191 ppt / 382 ppt
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm
Delineation based on CS57 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 560
Feet



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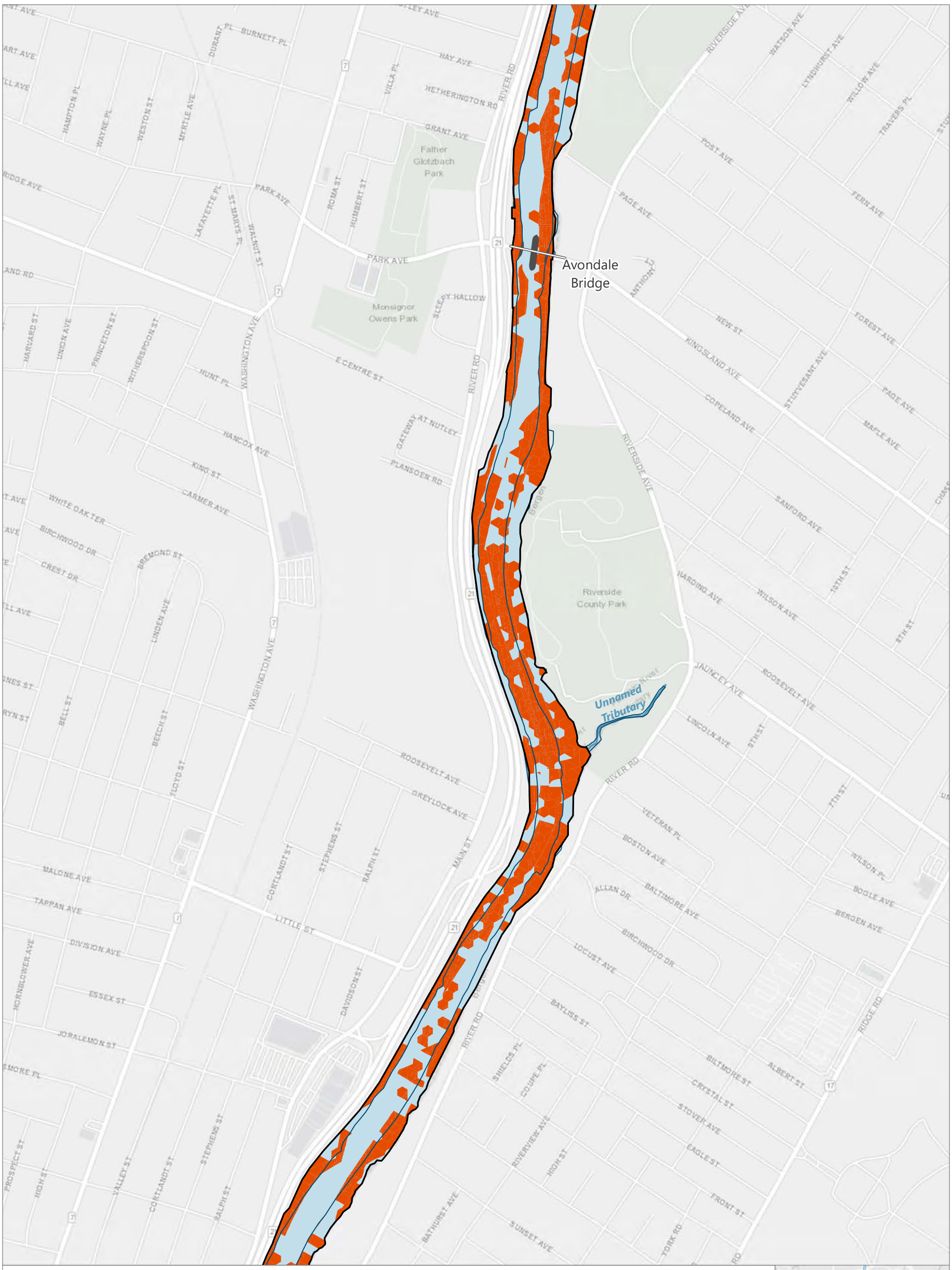
Filepath: \\Boston1\jobs\Passaic_CPG\DOCUMENTS\2019\FS_Report\source\App_B\20190808\Figure_5-5_CS57_75ppt_Model.mxd

Figure 5-5c

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 57 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface): 191 ppt / 382 ppt
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm
Delineation based on CS57 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

0 1,100
Feet

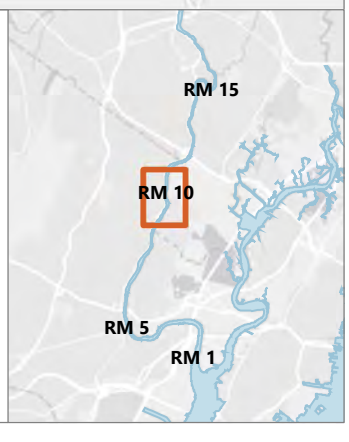


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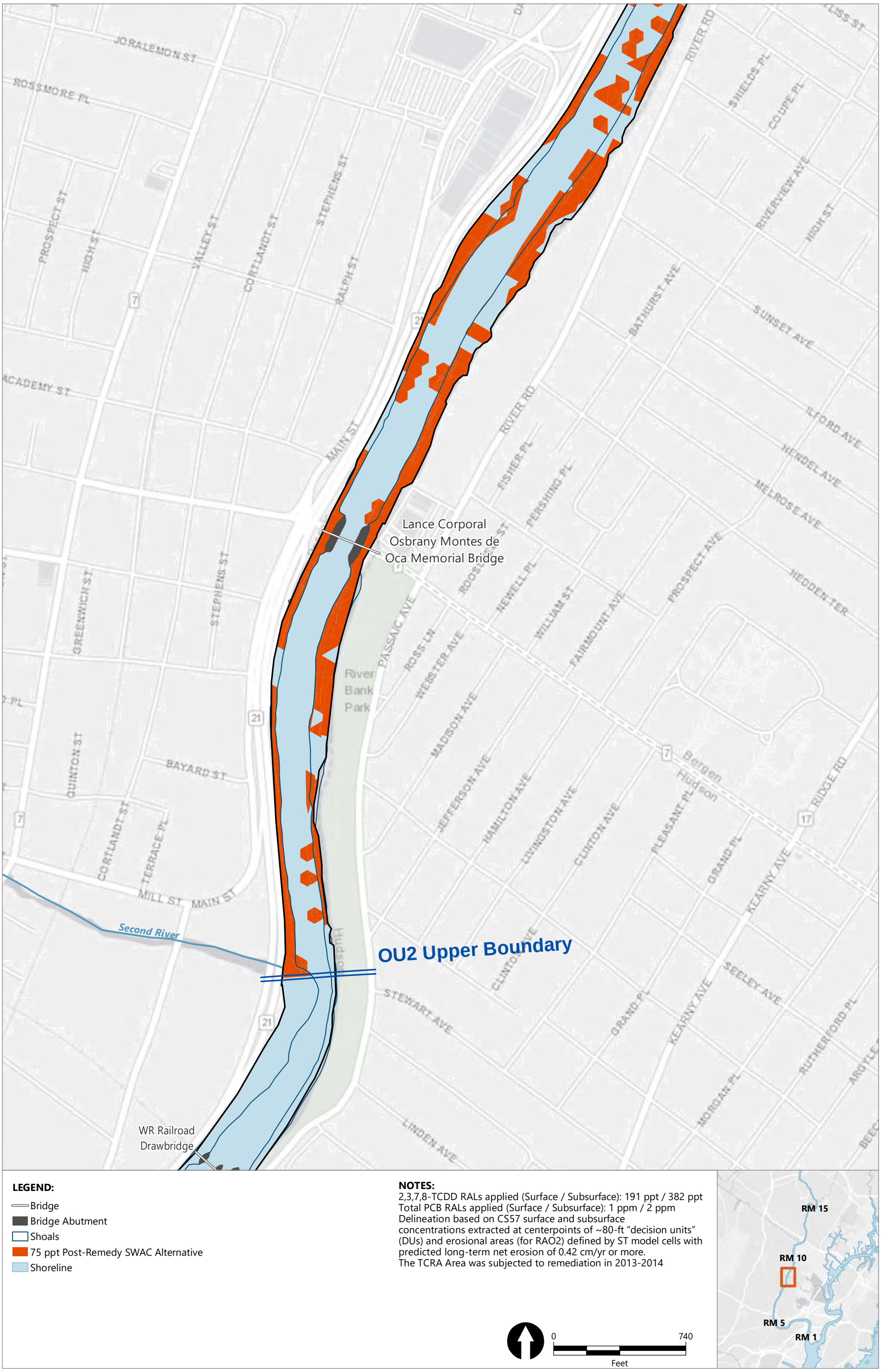
Figure 5-5d

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 57 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES:
2,3,7,8-TCDD RALs applied (Surface / Subsurface): 191 ppt / 382 ppt
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm
Delineation based on CS57 surface and subsurface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm/yr or more.
The TCRA Area was subjected to remediation in 2013-2014

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Figure 5-5e

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 57 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES: 2,3,7,8-TCDD RALs applied (Surface /Subsurface): 170 ppt / 340 ppt.
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm.
Delineation based on CS81 surface and sub surface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm /yr or more.
The TCRA Area was subjected to remediation in 2013-2014.

0 1,350
Feet

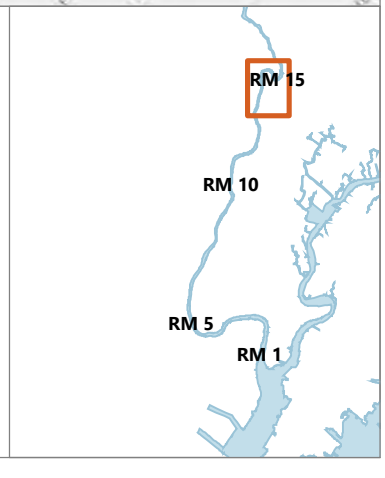

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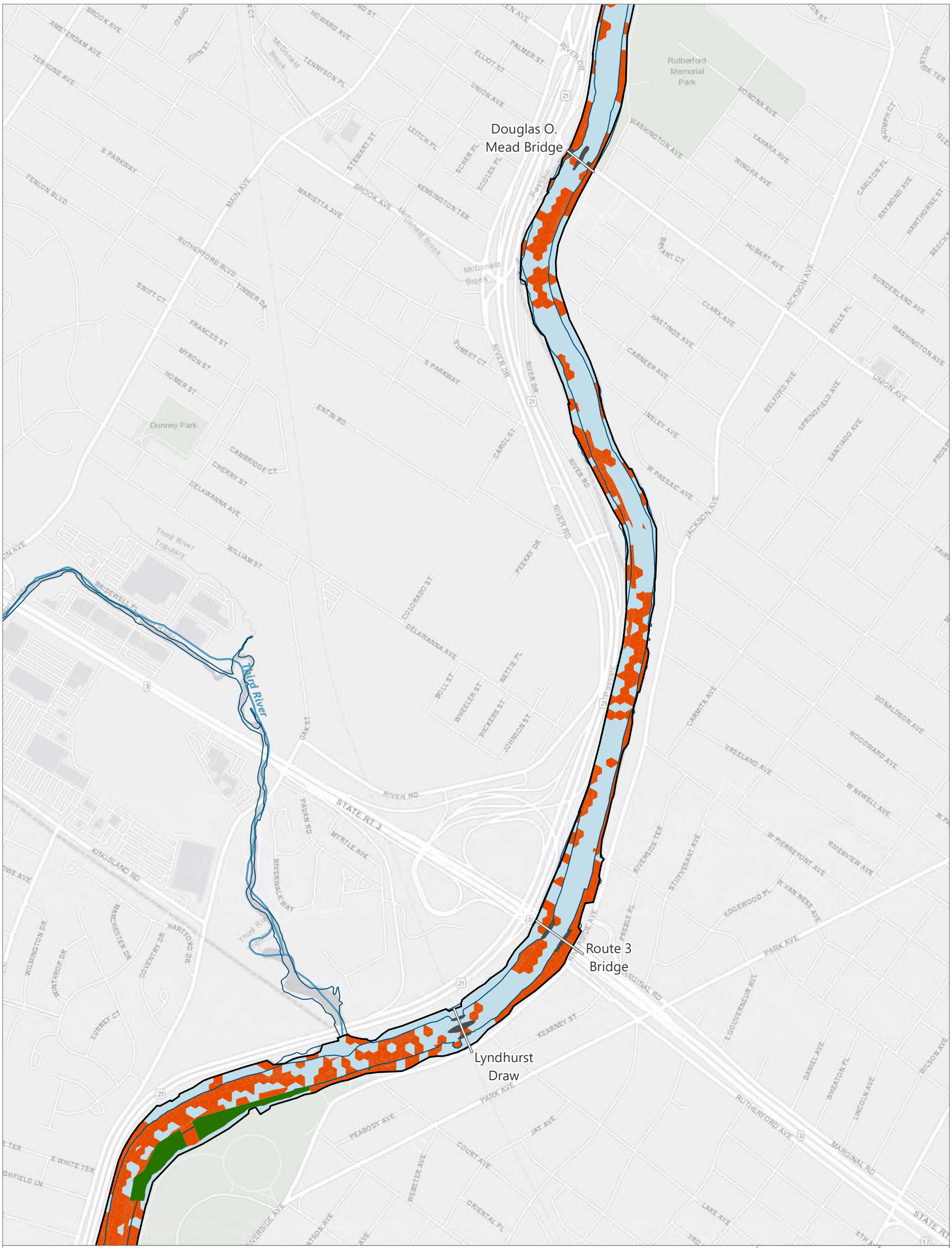
Figure 5-6a

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 81 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- TCRA remediated in 2013-2014
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES: 2,3,7,8-TCDD RALs applied (Surface /Subsurface): 170 ppt / 340 ppt.
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm.
Delineation based on CS81 surface and sub surface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm /yr or more.
The TCRA Area was subjected to remediation in 2013-2014.

0 1,540
Feet

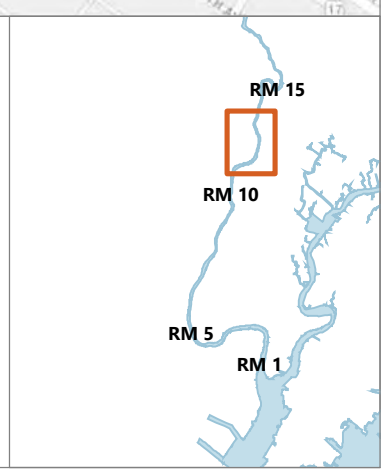


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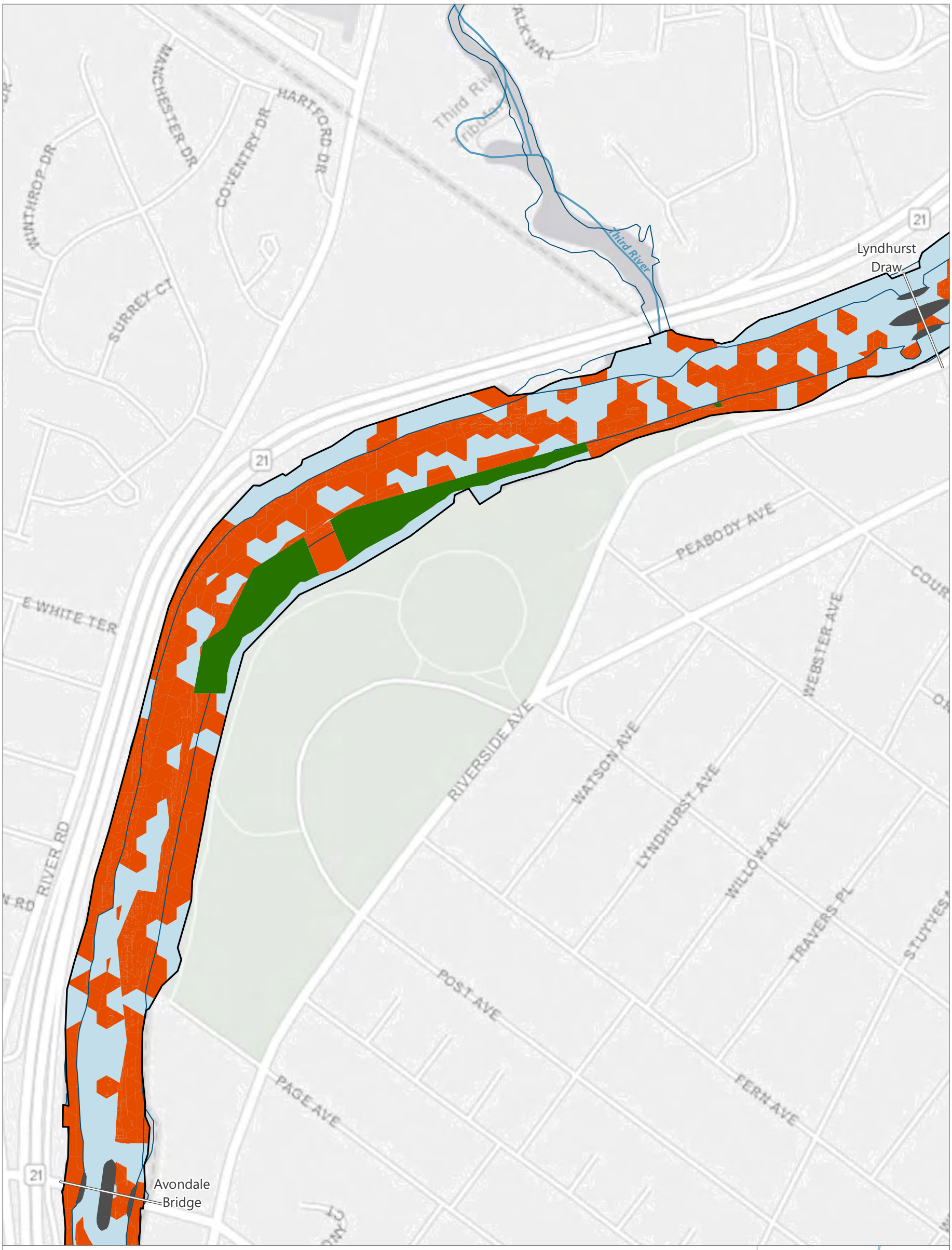
Figure 5-6b

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 81 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- TCRA remediated in 2013-2014
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES: 2,3,7,8-TCDD RALs applied (Surface /Subsurface): 170 ppt / 340 ppt.
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm.
Delineation based on CS81 surface and sub surface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm /yr or more.
The TCRA Area was subjected to remediation in 2013-2014.

0 720
Feet

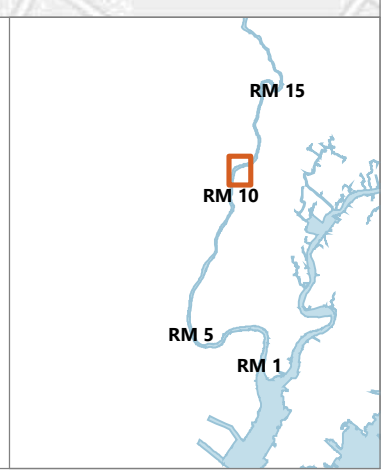


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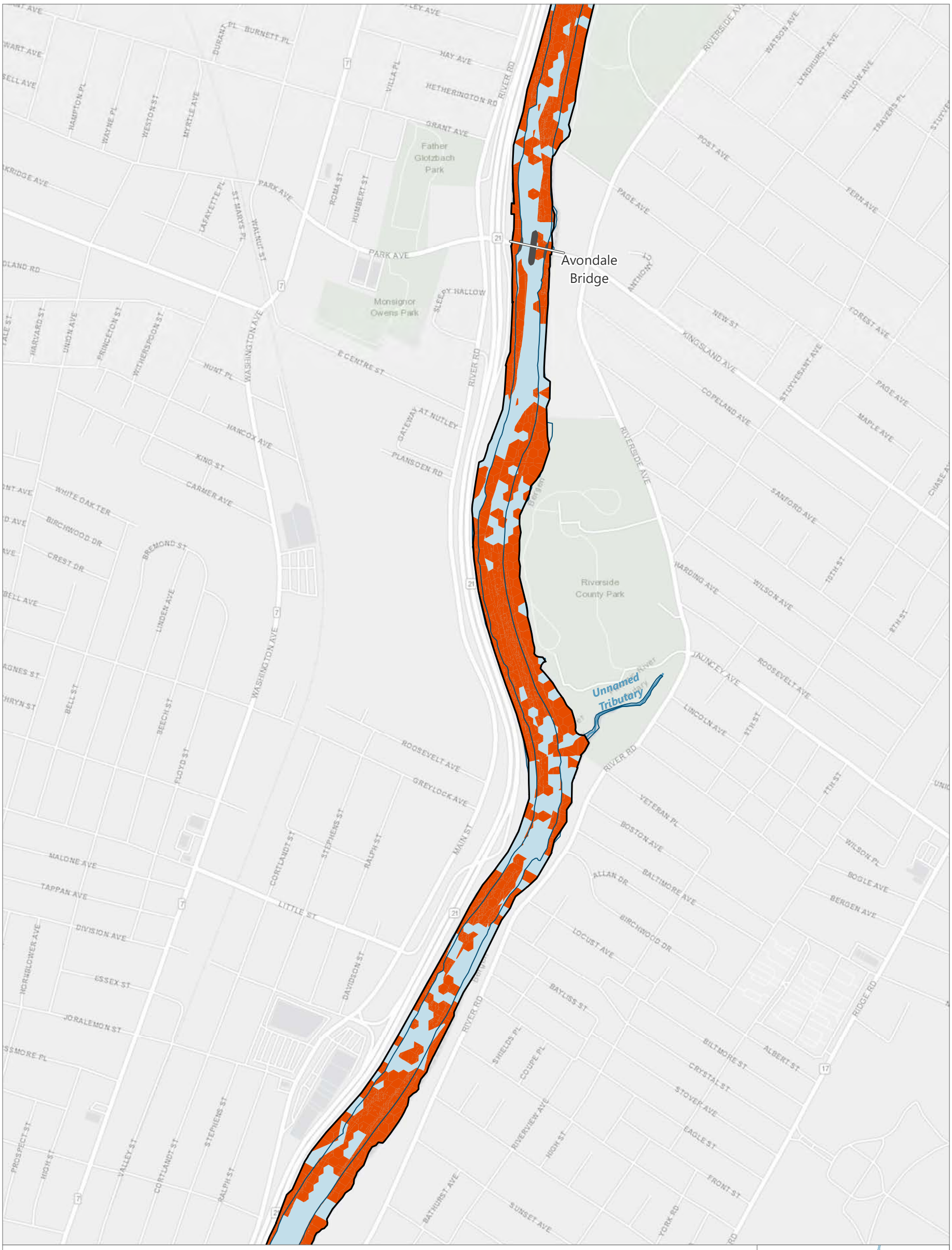
Figure 5-6c

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 81 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES: 2,3,7,8-TCDD RALs applied (Surface /Subsurface): 170 ppt / 340 ppt.
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm.
Delineation based on CS81 surface and sub surface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm /yr or more.
The TCRA Area was subjected to remediation in 2013-2014.

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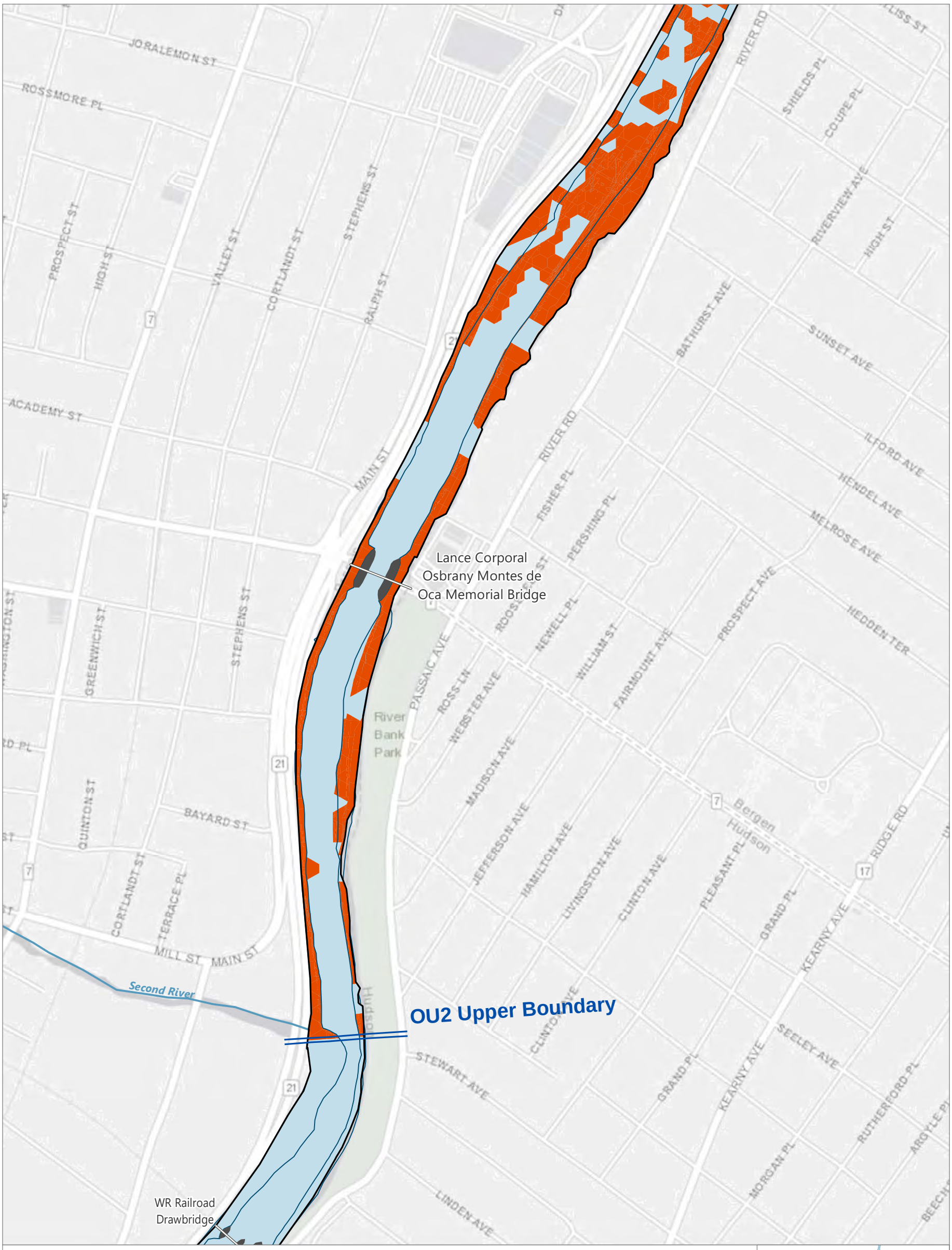
Figure 5-6d

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 81 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



LEGEND:

- Bridge
- Bridge Abutment
- Shoals
- 75 ppt Post-Remedy SWAC Alternative
- Shoreline

NOTES: 2,3,7,8-TCDD RALs applied (Surface /Subsurface): 170 ppt / 340 ppt.
Total PCB RALs applied (Surface / Subsurface): 1 ppm / 2 ppm.
Delineation based on CS81 surface and sub surface concentrations extracted at centerpoints of ~80-ft "decision units" (DUs) and erosional areas (for RAO2) defined by ST model cells with predicted long-term net erosion of 0.42 cm /yr or more.
The TCRA Area was subjected to remediation in 2013-2014.

0 940
Feet

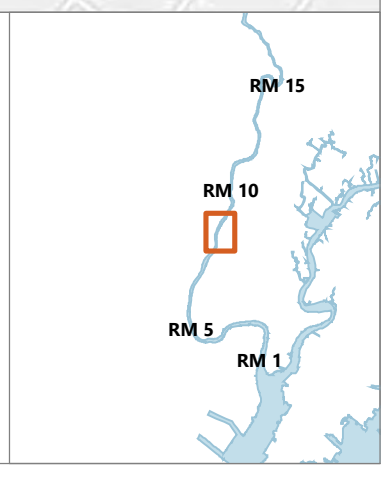


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Figure 5-6e

Remedial Footprint for the 75 ng/kg Post-Remedy 2,3,7,8-TCDD SWAC Alternative for Conditional Simulation 81 for Model Projections

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

Attachment 1
Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2

Lower Passaic River Feasibility Study
Proposal for the Subsurface Remedial Action Level
to Achieve Remedial Action Objective 2

The goal of Remedial Action Objective (RAO) 2 is to control subsurface sediments (sediments greater than 6 inches below the sediment bed) from becoming sources of 2,3,7,8-TCDD and total PCBs by remediating sediments between river mile (RM) 8.3 and RM 15 that have a demonstrated potential for erosion to expose subsurface concentrations above defined subsurface remedial action levels (RALs) established for 2,3,7,8-TCDD and total PCBs.

This potential is defined by the magnitude of the subsurface concentrations, the area over which they exist and the likelihood of exposure. In simple terms, this potential can be described as follows:

$$Potential = \mathcal{L}cA$$

where:

$\mathcal{L}$	=	likelihood of exposure
c	=	concentration
A	=	area

The product of $\mathcal{L}$ and c can be thought of as the effective subsurface concentration. A low concentration with a high likelihood of exposure may be as effective in its potential to be a source as a much higher concentration with a low likelihood of exposure.

The area (A) can be identified by bed elevation changes between multibeam bathymetric surveys conducted in 2007, 2008, 2010, 2011, and 2012 (e.g., using the "Erosional" and "Erosion and Deposition" portions of the river bottom identified in Section 4 of the Remedial Investigation [RI] Report). For areas not covered by the bathymetric surveys (as documented in the RI Report), the predictions of the Cooperating Parties Group (CPG) Lower Passaic River (LPR) sediment transport model can be used.

Although the upper 9 miles of the LPR are thought to be in a dynamic equilibrium on the large scale, erosion does occur on local scales as evidenced by the 2007 to 2012 multibeam survey series. Erosion of sediments is controlled by the shear stress at the river bottom and the resistance of the sediments to this stress. The shear stress is driven by the velocity of the overlying water and the roughness of the sediment surface. The velocities vary with the tides and with the upstream river flow.[1] They are greatest during extreme high-flow events. The spatial patterns of high-flow-event velocities are driven by river

[1]They are also influenced by waves and boats but to a much less extent, except in localized areas

geometry, sinuosity, and bottom roughness. Though there is some randomness to this pattern, it is largely predictable with some areas sheltered from high stresses and others exposed to these stresses during each event. Erosion patterns in the multibeam bathymetry surveys indicate that areas experiencing the highest stresses typically include the channel bottom and side-slopes, particularly outside channel side-slopes on bends or in regions of flow constriction (e.g., near bridge abutments). Areas of cyclical erosion and deposition, such as those observed along the inner bend of the RM 10.9 shoal, likely reflect the accumulation of mobile sediments on top of a bed that has been armored by past high-flow events, making it more resistant to further erosion.

Buried 2,3,7,8-TCDD concentrations (which will be mapped by future high-density pre-design sediment sampling) are generally expected to have a low likelihood (£) of exposure. This is so because they are still in the subsurface despite being subjected to a number of extreme high-flow events, including a 90-year flow that resulted from Hurricane Irene in 2011. The exception to this are locations where the buried concentrations are associated with recently deposited sediments that may be more vulnerable to erosion than older sediments. In this case, the buried concentrations likely reflect recent water column particulate concentrations depositing onto the sediment bed and not the much higher concentrations associated with older sediments.

The likelihood (£) that sediments that experienced erosion of 6 inches or more would experience an additional 6 inches or more of erosion was investigated using the bed elevation changes between multi-beam bathymetry surveys (the threshold of 6 inches was identified in the RI Report based on the accuracy of the multibeam surveys). Sediments that experienced erosion between surveys in 2008 and 2010 were chosen as the test locations. Erosion potential was likely high during this period because of a 25-year flow event (about 16,000 cubic feet per second [cfs]) that occurred about 1 month before the 2010 bathymetric survey.

These locations were tracked for subsequent elevation change in response to two extreme-flow events (greater than 10,000 cfs) that occurred prior to the bathymetric survey in October 2011, including the 90-year flow associated with Hurricane Irene in September 2011. They are not the only locations where erosion might occur in the later events, but they are tests for the proposition that the armoring and deepening caused by prior erosion reduces the likelihood of further erosion.

Between RM 8.3 and RM 15, 26.4 acres experienced erosion between 2008 and 2010 (6 inches or more). Of these, only 6.3 acres experienced further erosion between 2010 and 2012 of 6 inches or more, with the remainder experiencing no measurable change or net deposition[2] (Table 1). A map of these locations is provided in Figure 1.

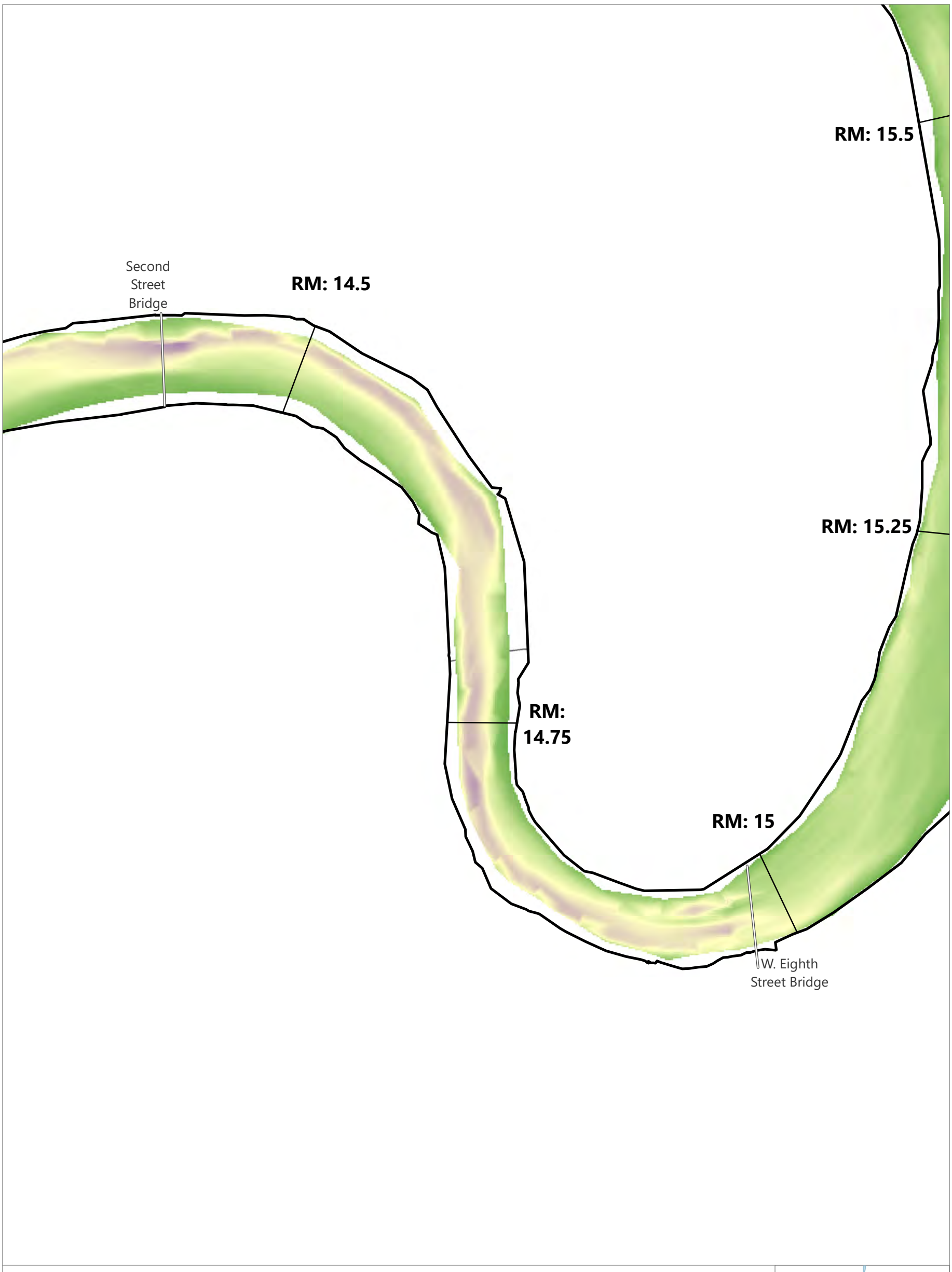
[2] The categories presented in Table 1 are based on the maximum erosion observed when comparing the 2010 survey to both the 2011 and 2012 surveys.

These findings suggest that $\mathcal{L}$ may be expected to be about 0.25. This yields an effective subsurface concentration ($\mathcal{L} * c$ as defined above) that is one fourth the measured concentration. Thus, a subsurface RAL four times the surface sediment RAL should be considered equivalent to the surface sediment RAL from the perspective of controlling erosional impacts to the surface sediment surface-weighted average concentration (SWAC).

To be conservative, a value of 0.5 was chosen for assessing the potential for erosion to provide a source of subsurface concentrations of 2,3,7,8-TCDD and total PCBs. Therefore, the CPG proposes to use a subsurface RAL that is two times the surface RAL for developing the RAO 2 subsurface footprints for the remedial alternatives in the Interim Remedy Feasibility Study for the upper 9 miles.

Table 1
Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data (RM 8.3 to RM 15)

Maximum Subsequent Erosion in 2008 to 2010 Erosional Areas	Area (acres)	% of Erosional Areas
Depositional/No Change (less than 6 inches)	20.1	76%
Erosional, 6 to 12 inches	5.2	20%
Erosional, greater than 12 inches	1.1	4%
Total	**26.4**	**100%**



LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 440
Feet

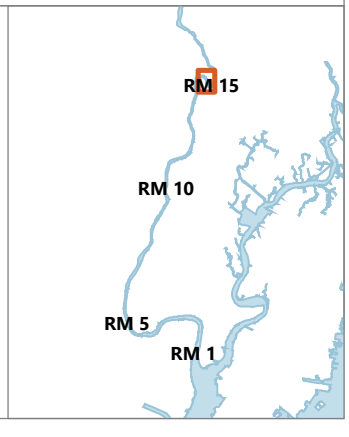


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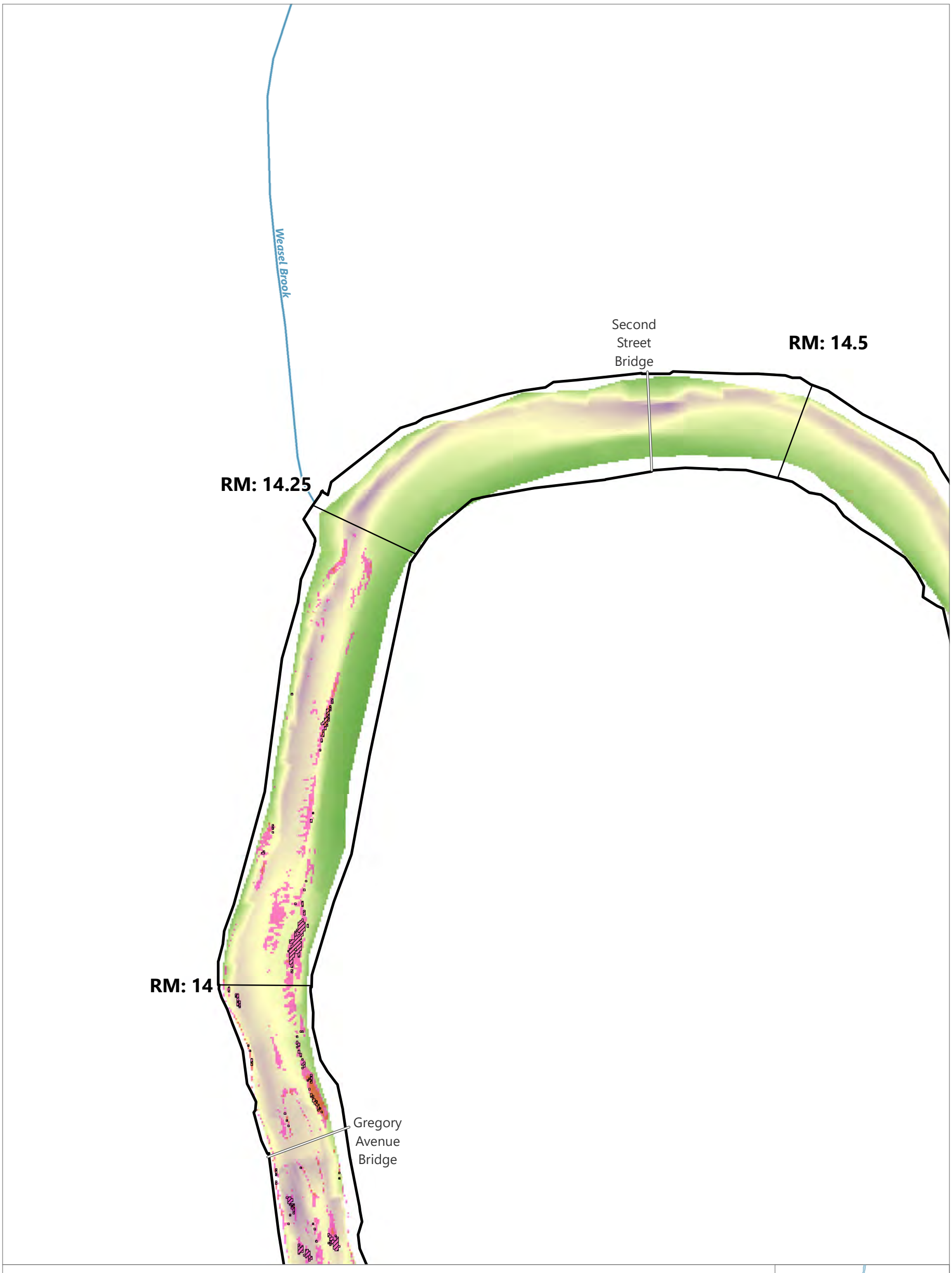
Figure 1a

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

- Bridge
- River Miles
- Tributaries

2004 Bathymetry (feet in NGVD)

- High: 11.3
- Middle: -11.1
- Low: -34.4

2008 to 2010 Erosional Areas

- 6 to 12 inches
- >= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

- 6 to 12 inches
- >= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 400
Feet

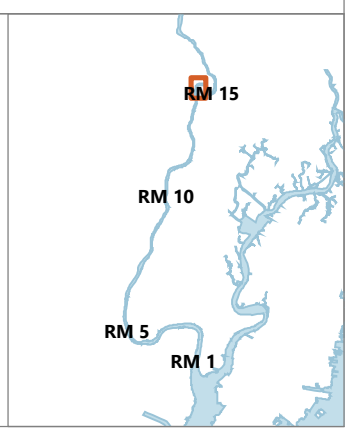


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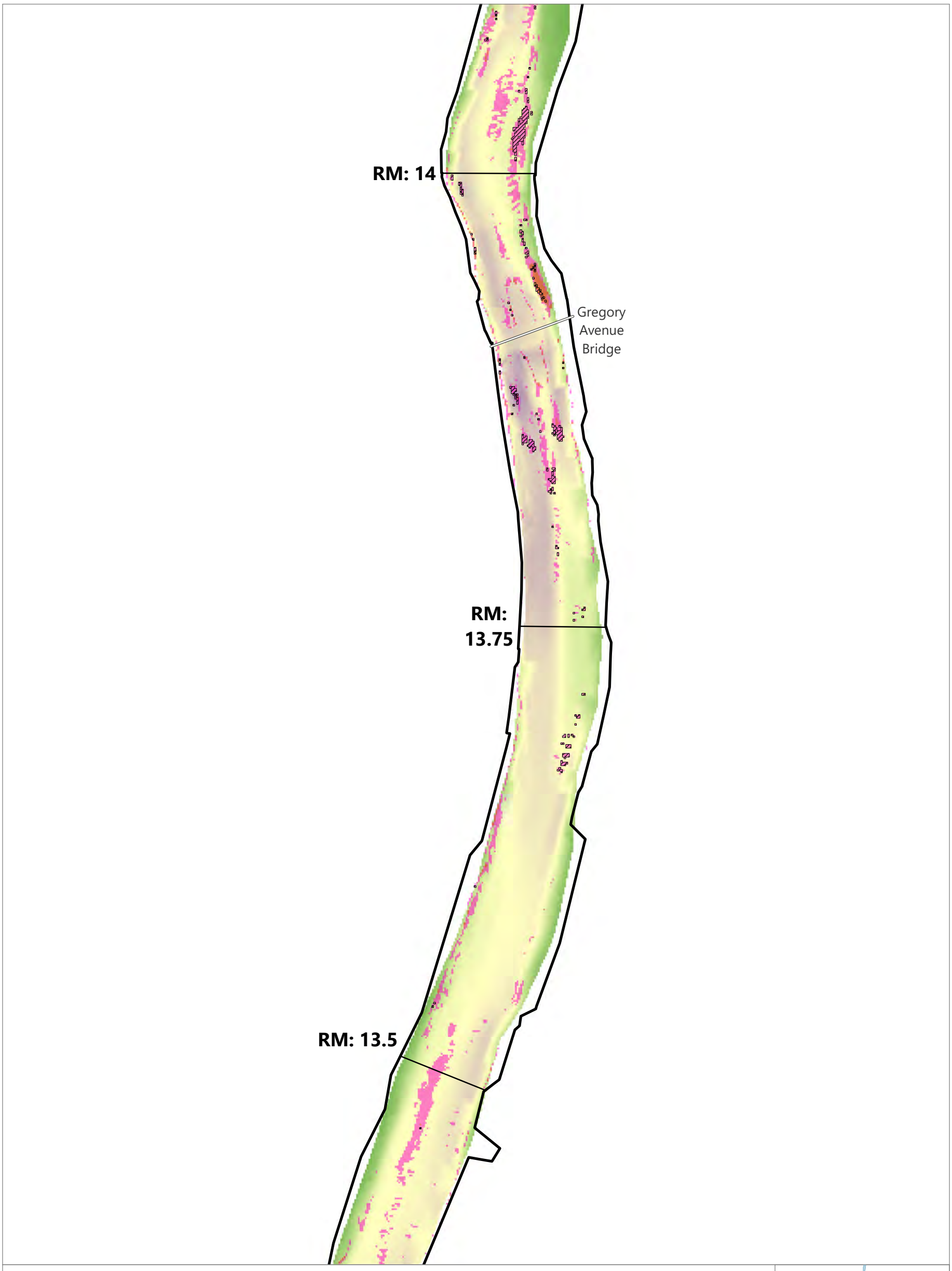
Figure 1b

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 400
Feet

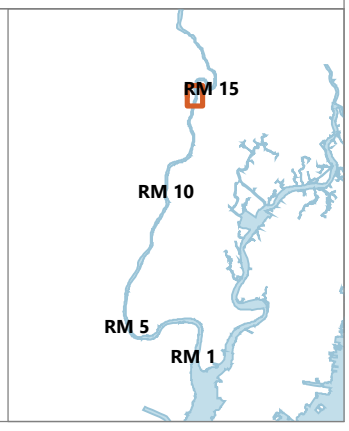


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Figure 1c

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

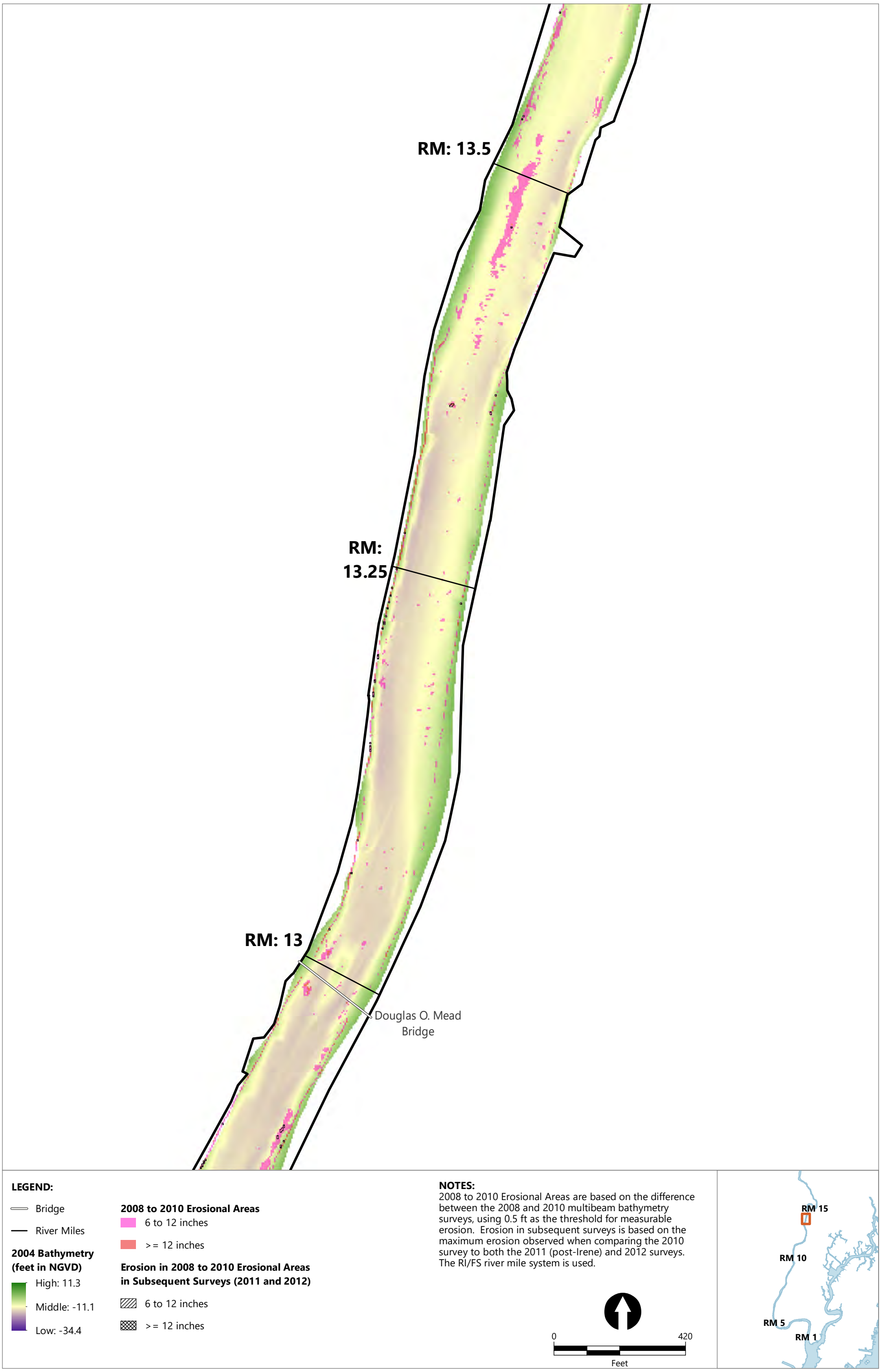

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Figure 1d

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

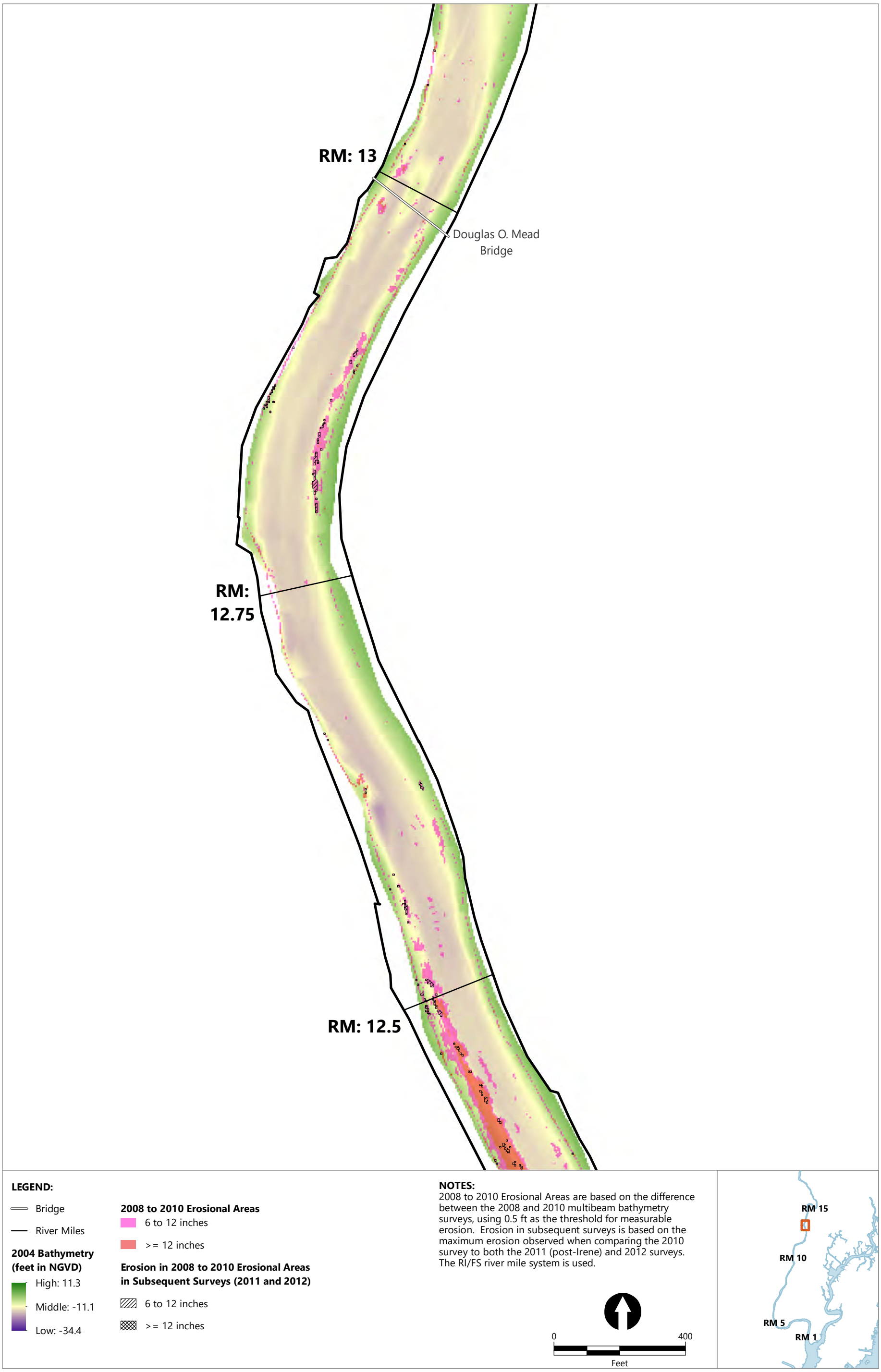

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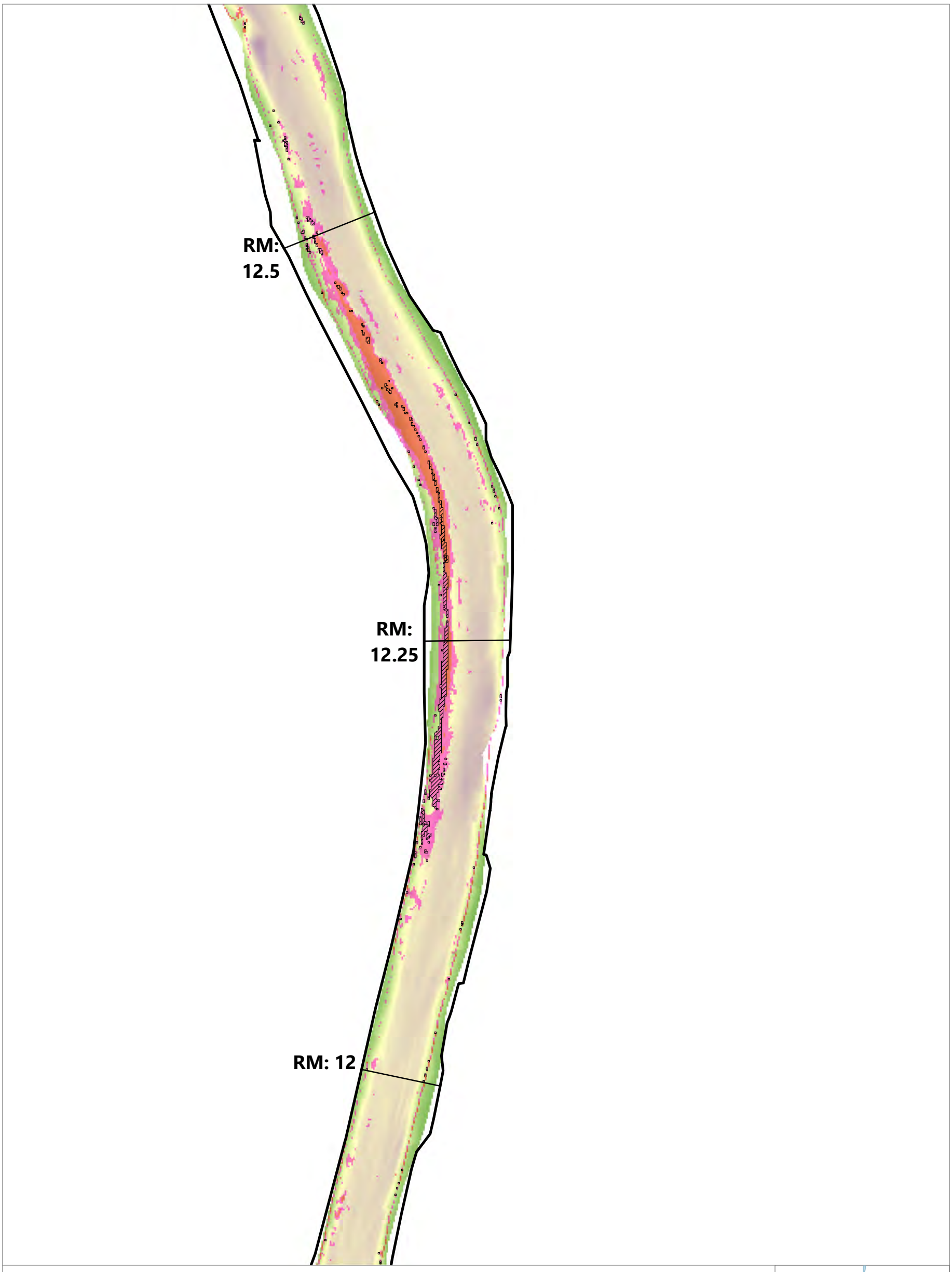
Figure 1e

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 420
Feet

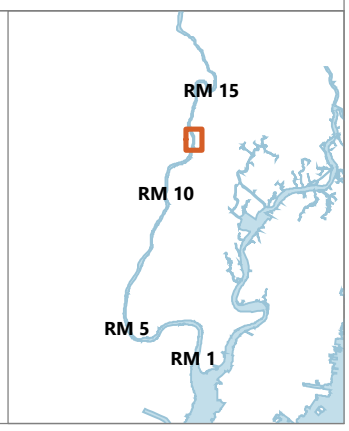


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Figure 1f

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

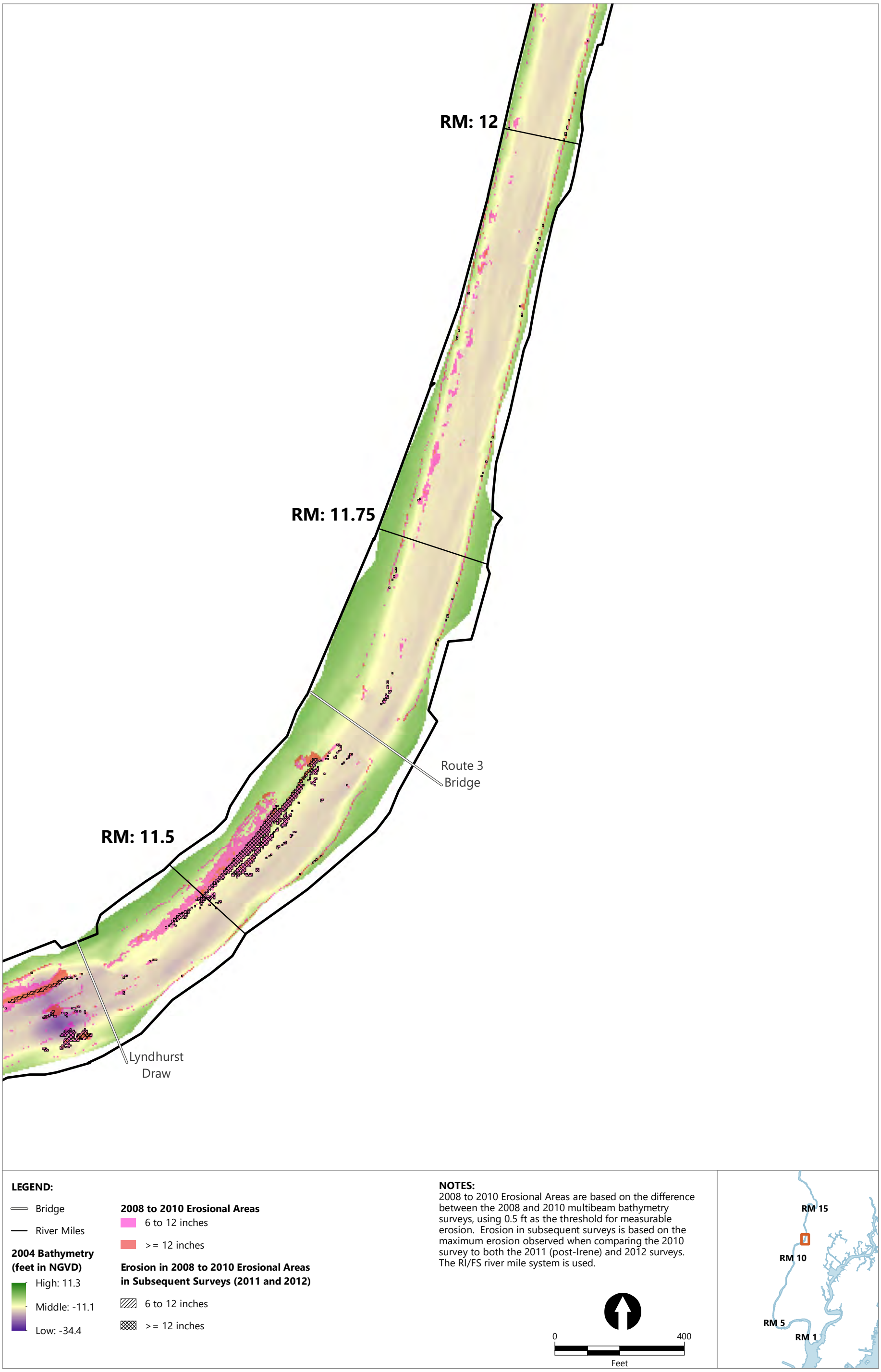

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Figure 1g

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

LEGEND:

- Bridge
- River Miles
- Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

- 6 to 12 inches
- >= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

- 6 to 12 inches
- >= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 400
Feet

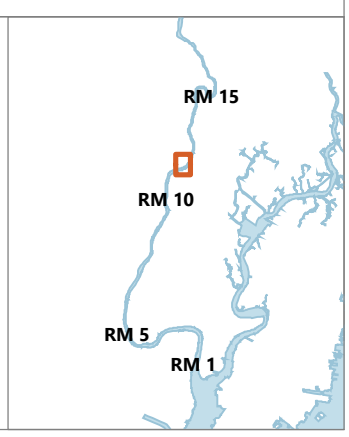

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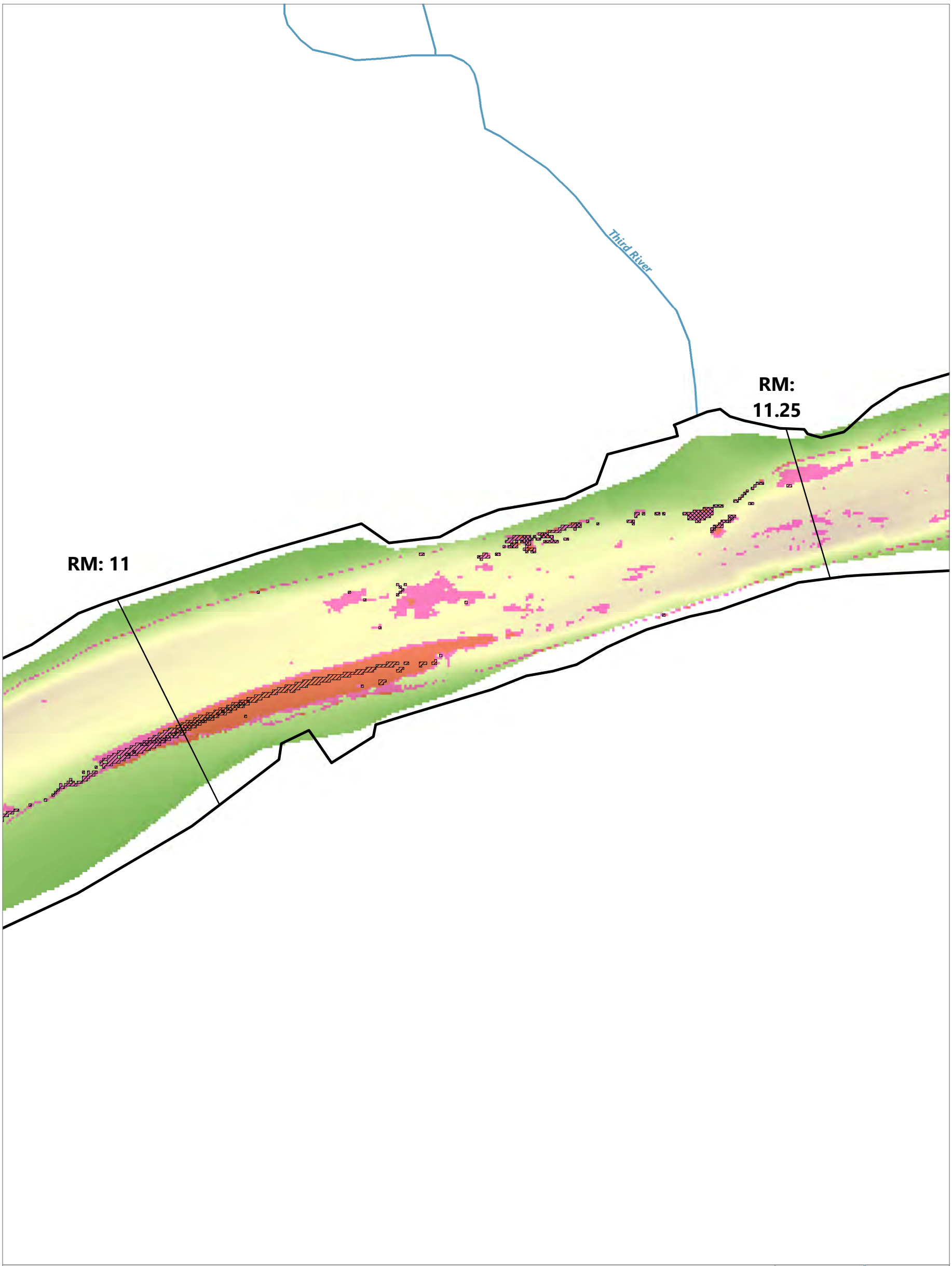
Figure 1h

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

River Miles

Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 280
Feet

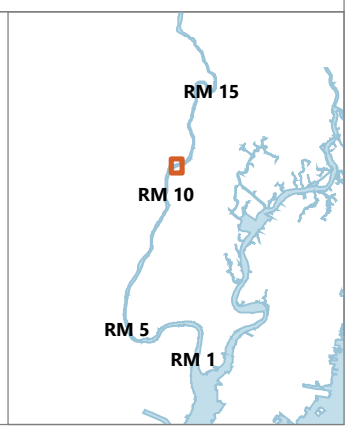


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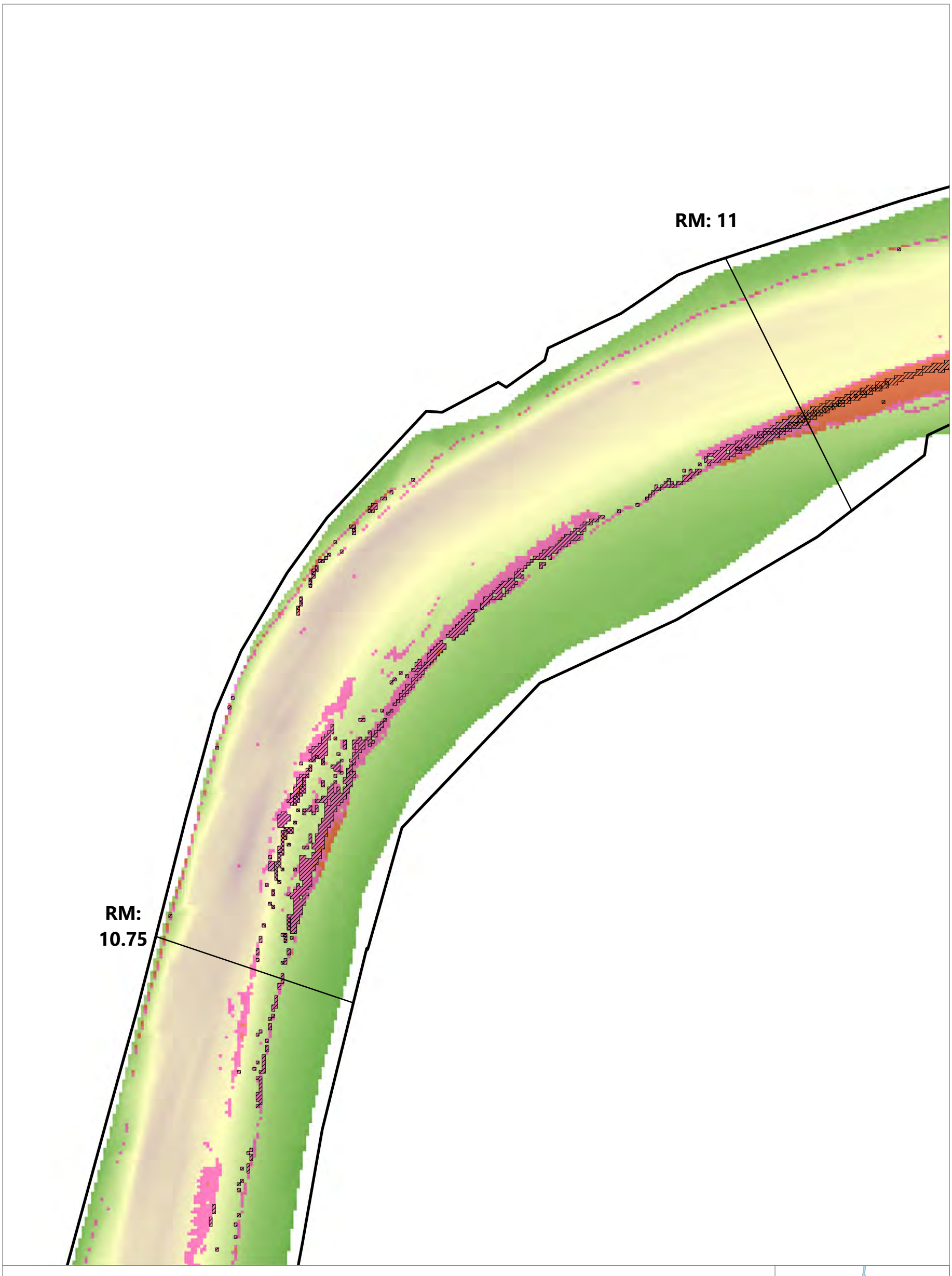
Figure 1i

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

> = 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 220
Feet

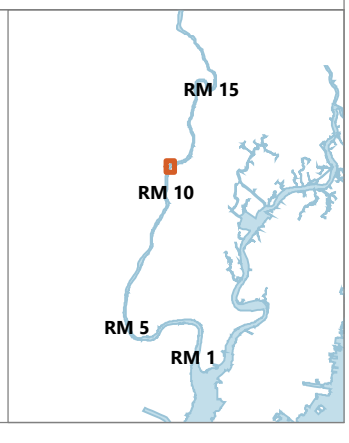


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Figure 1j

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

LEGEND:

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

> = 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 200
Feet

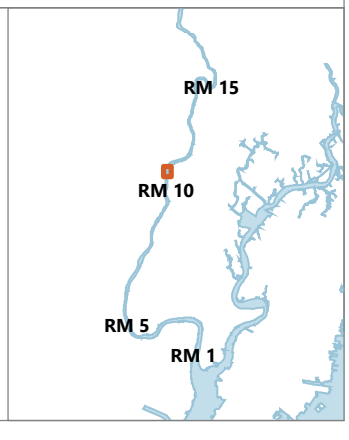

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Figure 1k

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

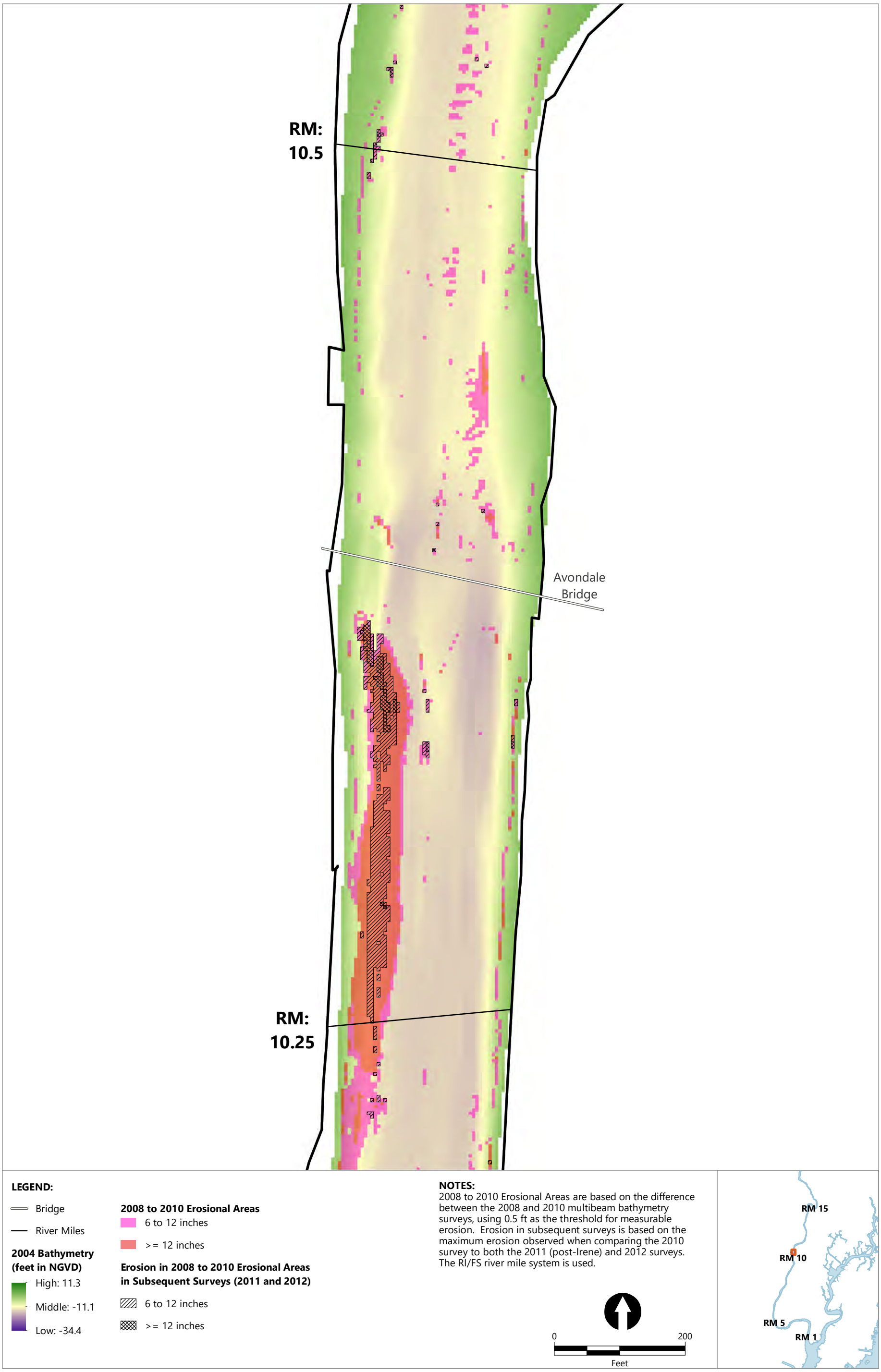

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Figure 1l

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

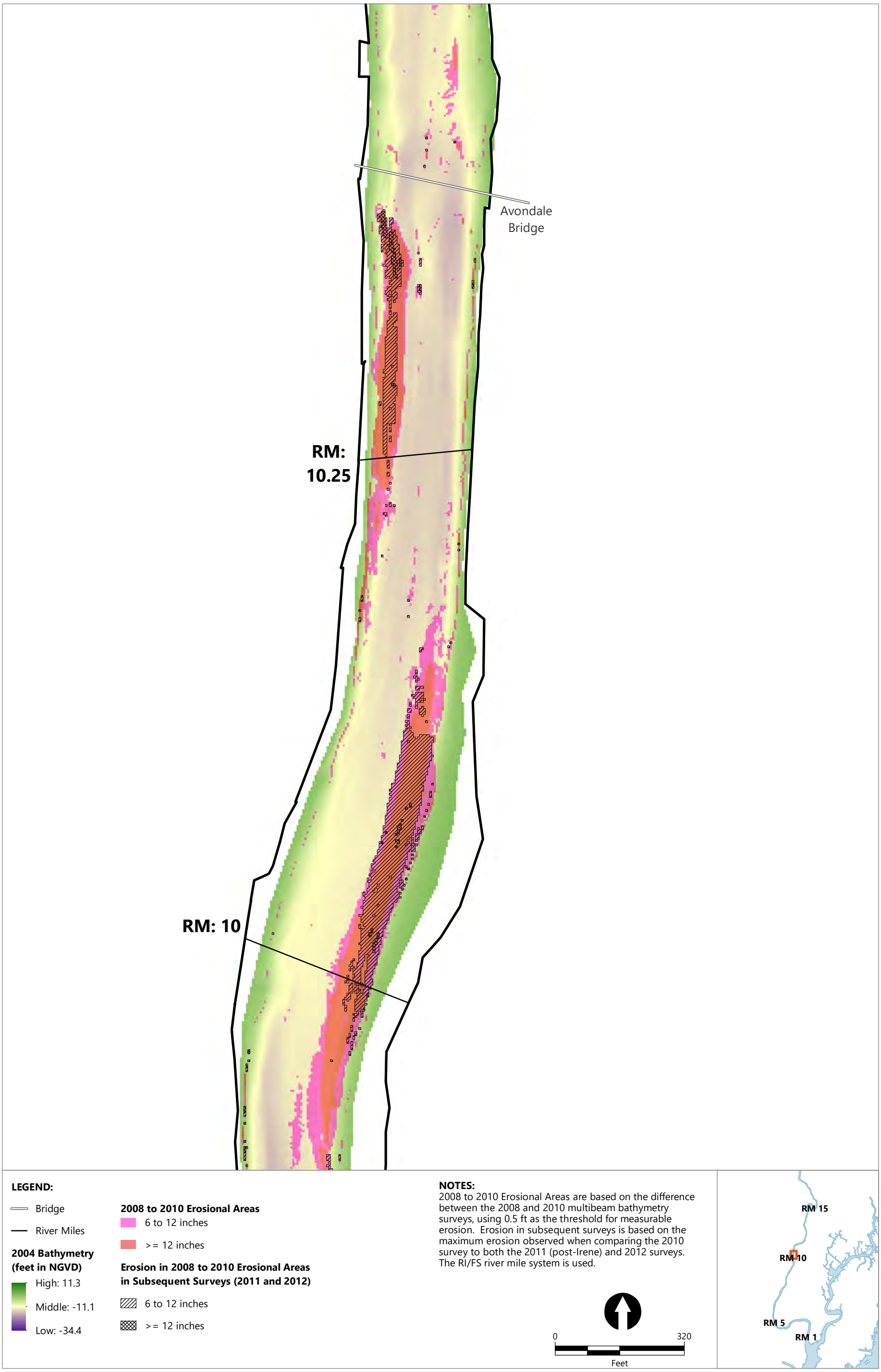

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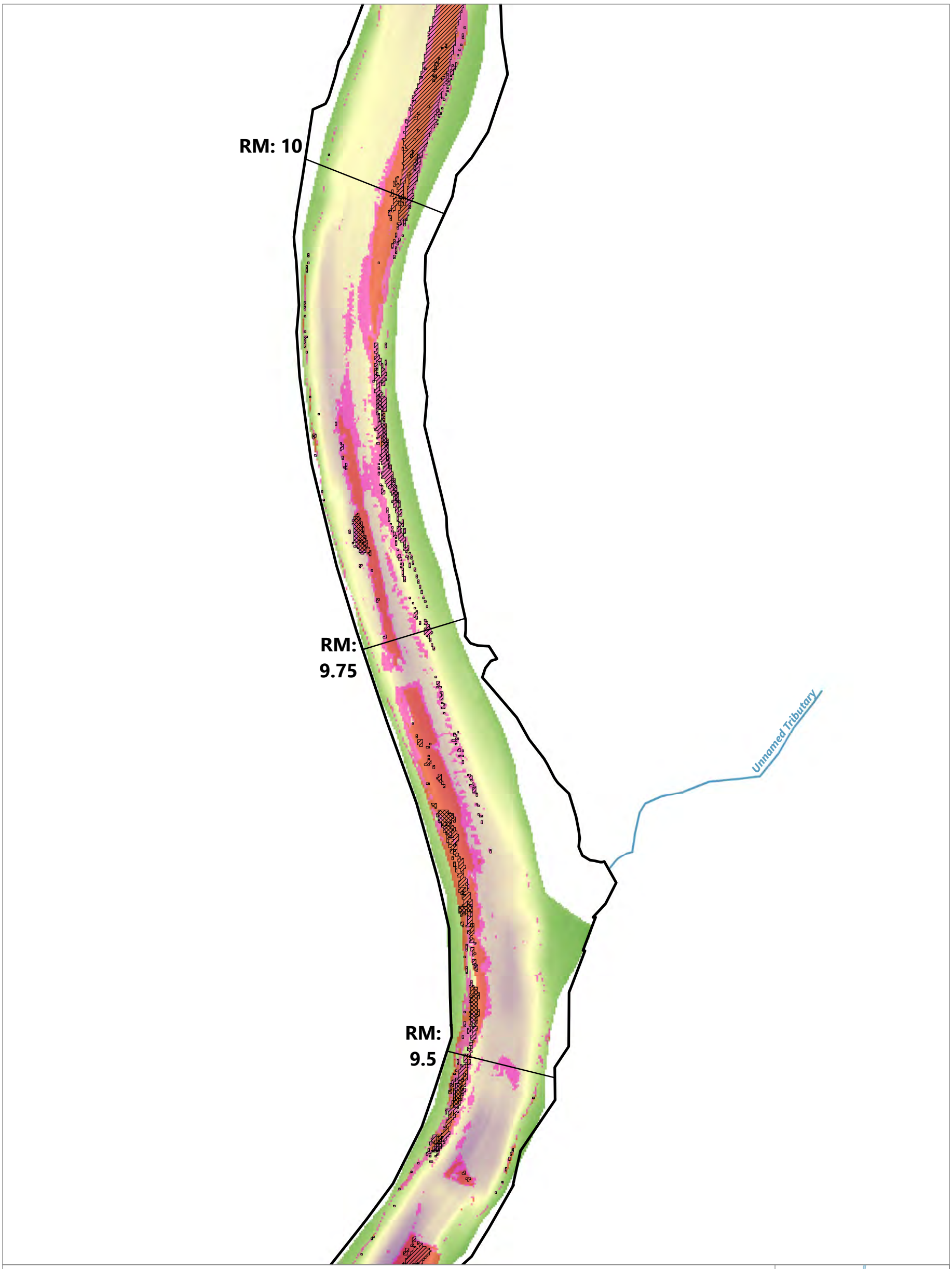
Figure 1m

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

River Miles

Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 420
Feet

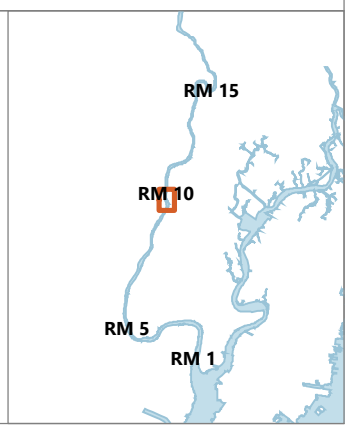


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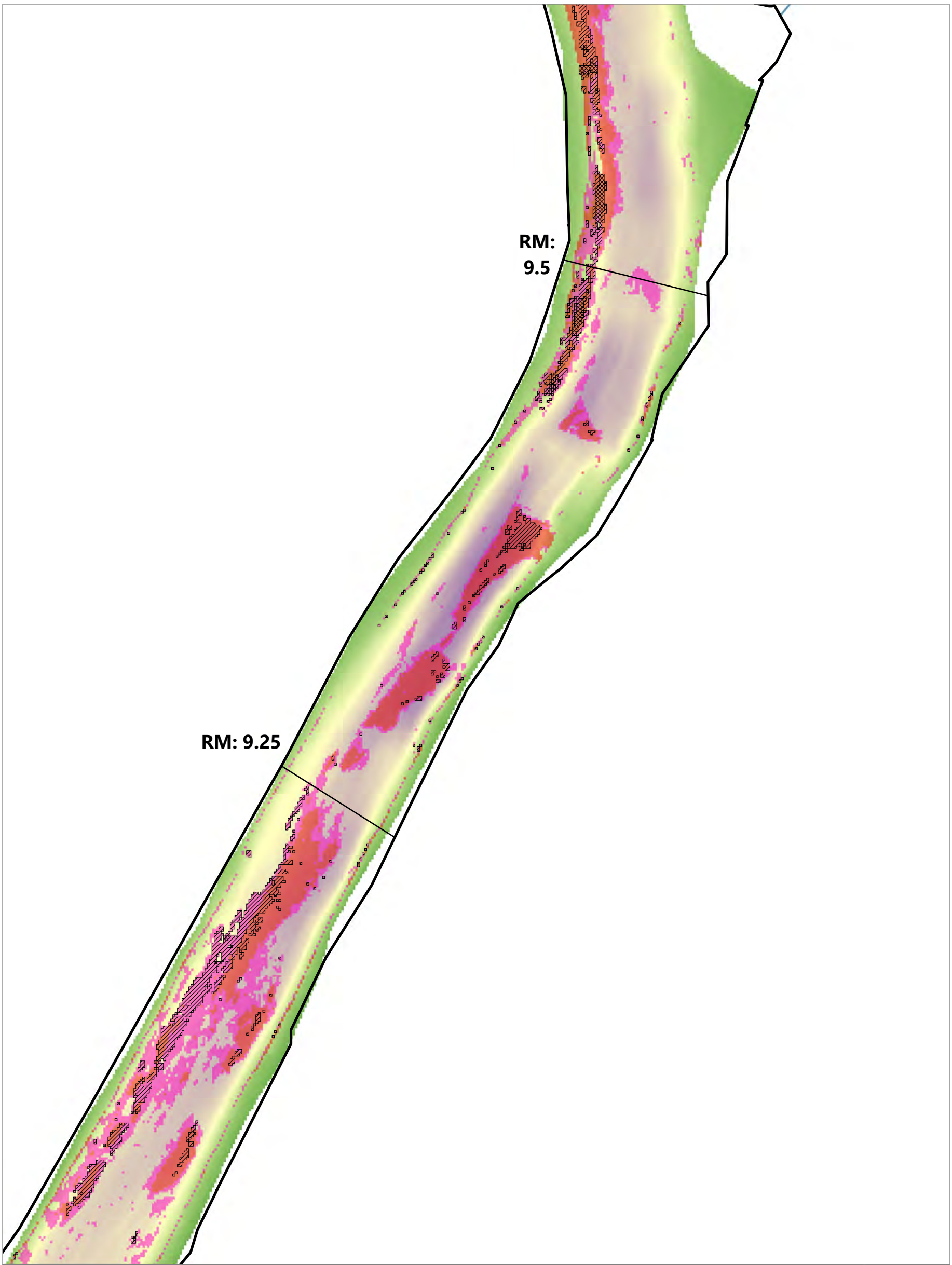
Figure 1n

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

River Miles

Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

>= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

>= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 300
Feet

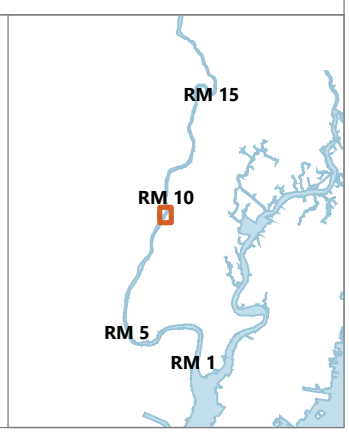


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Figure 1o

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

LEGEND:

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

> = 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 400
Feet

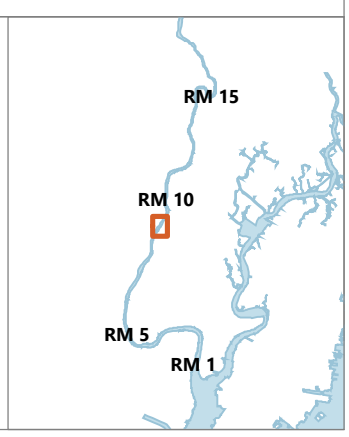

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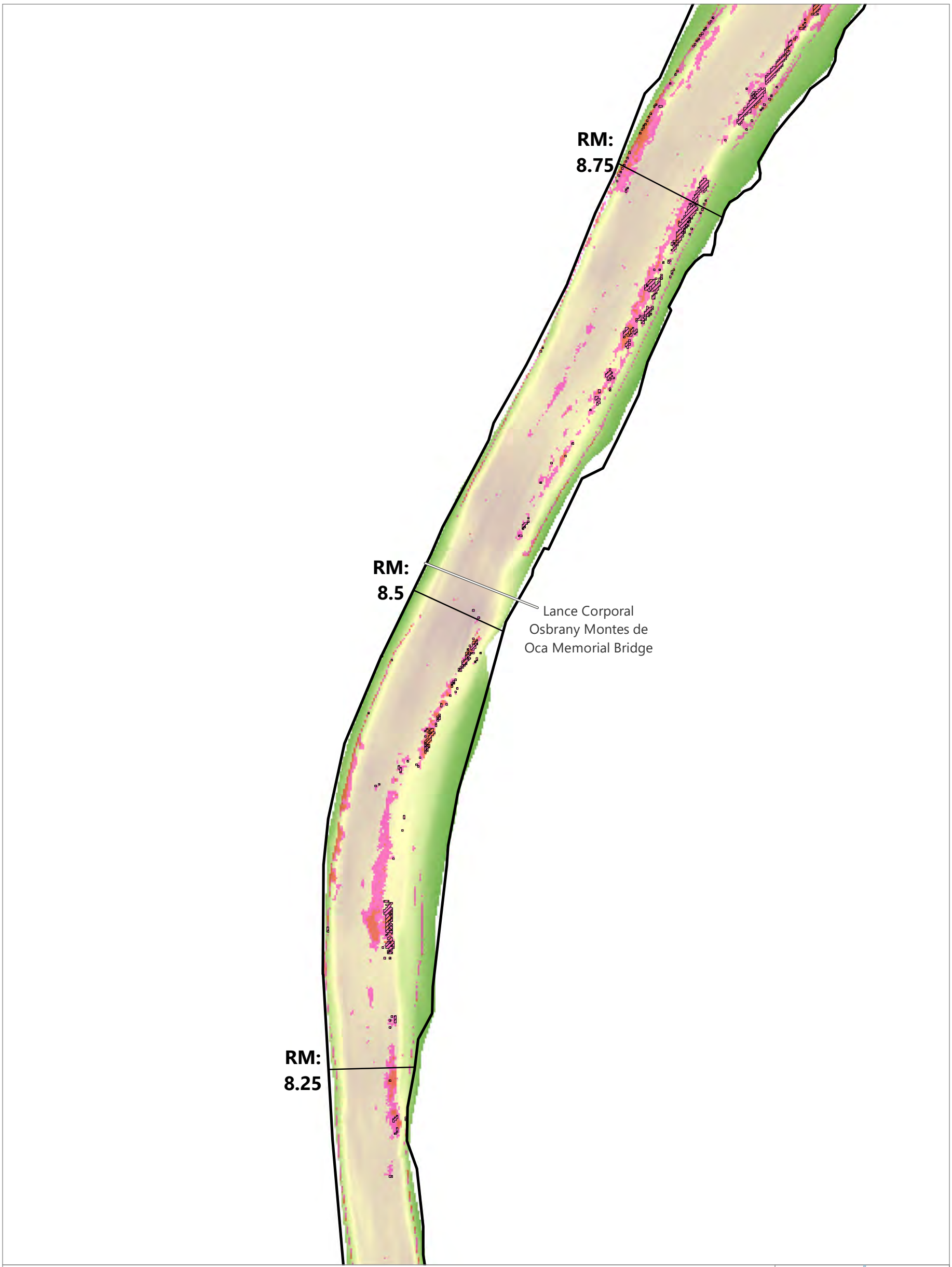
Figure 1p

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

Bridge

River Miles

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

6 to 12 inches

> = 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

6 to 12 inches

> = 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 400
Feet

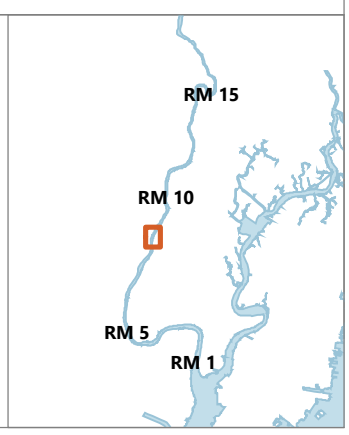


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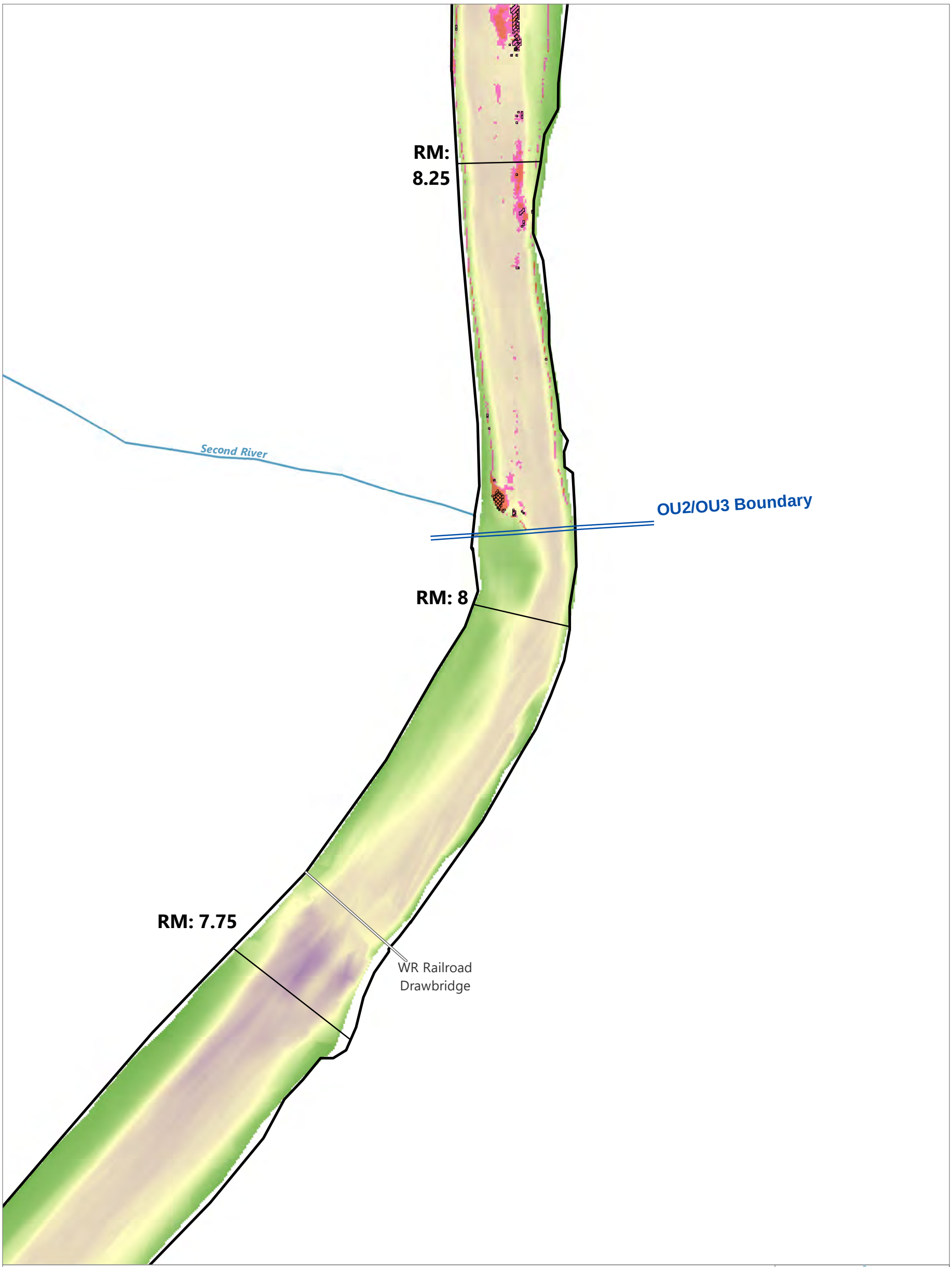
Figure 1q

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study



LEGEND:

- Bridge
- River Miles
- Tributaries

2004 Bathymetry (feet in NGVD)

High: 11.3

Middle: -11.1

Low: -34.4

2008 to 2010 Erosional Areas

- 6 to 12 inches
- >= 12 inches

Erosion in 2008 to 2010 Erosional Areas in Subsequent Surveys (2011 and 2012)

- 6 to 12 inches
- >= 12 inches

NOTES:
2008 to 2010 Erosional Areas are based on the difference between the 2008 and 2010 multibeam bathymetry surveys, using 0.5 ft as the threshold for measurable erosion. Erosion in subsequent surveys is based on the maximum erosion observed when comparing the 2010 survey to both the 2011 (post-Irene) and 2012 surveys. The RI/FS river mile system is used.

0 420
Feet

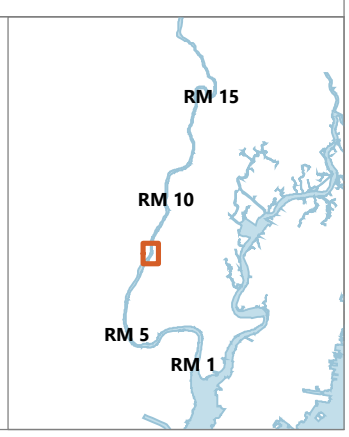


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Figure 1r

Analysis of Subsequent Erosional Behavior in 2008 to 2010 Erosional Areas Using Multibeam Bathymetry Data

Proposal for the Subsurface Remedial Action Level to Achieve Remedial Action Objective 2
Lower Passaic River Study Area Remedial Investigation/Feasibility Study

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Interim Remedy Feasibility Study Model Projections

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ATTACHMENT

Attachment 1	Supplemental 18-Year IR FS Model Projection Time Series

ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
BC	boundary condition
CARP	Contaminant Assessment and Reduction Project
cfs	cubic feet per second
CFT	contaminant fate and transport
COC	chemical of concern
CPG	Cooperating Parties Group
CS	conditional simulation
ECOM	Estuarine Costal Ocean Model
FFS	Focused Feasibility Study
foc	fraction of organic carbon
FS	feasibility study
HD	hydrodynamic
HQI	HDR|HydroQual
IC	initial condition
IR	Interim Remedy
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
MNR	Monitored Natural Recovery
NA	No Action
ng/kg	nanograms per kilogram
OC	organic carbon
PCB	polychlorinated biphenyl
RI	remedial investigation
RM	river mile
ST-SWEM	Sediment Transport-System Wide Eutrophication Model
SWAC	surface area-weighted average concentration
ROD	Record of Decision

ST	sediment transport
tetra-CB	tetrachlorobiphenyl
USEPA	U.S. Environmental Protection Agency
WY	water year

1 Introduction

A suite of models was developed to support the Remedial Investigation (RI)/Feasibility Study (FS) in the Lower Passaic River Study Area (LPRSA), including a hydrodynamic (HD) model, a sediment transport (ST) model, an organic carbon (OC) transport model, a contaminant fate and transport (CFT) model, and a bioaccumulation model.[1] The components up through the CFT model have gone through significant development to adequately represent the processes controlling the fate and transport of chemicals of concern (COC) in the LPRSA, and they can be used to provide estimates of future COC concentrations and fluxes in surface sediment and the water column under baseline conditions and active remediation scenarios. These models have been approved by the U.S. Environmental Protection Agency (USEPA) in 2019 (USEPA 2019) for use in a comparative evaluation of the Source Control Interim Remedy (IR) FS remedial alternatives. This use is tempered by the uncertainty of the model predictions. Because of this uncertainty, model predictions should only be used alongside other lines of evidence, and in a manner consistent with the IR FS supporting document developed in collaboration with USEPA, New Jersey Department of Environmental Protection, and Cooperating Parties Group (CPG) *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS* (CPG 2019). This appendix provides an overview of the modeling framework developed for the LPRSA and its application to evaluate remedial alternatives for the IR FS. A brief description of the numerical models is provided in Section 2. The approach to simulating remedial alternatives is described in Section 3. Select projection simulation results are presented in Section 4 and Attachment 1 to provide additional information in support of the comparison of alternatives in Section 8 of the main FS report.

[1] The bioaccumulation model is still being developed by the Cooperating Parties Group (CPG) under the supervision of the U.S. Environmental Protection Agency (USEPA) and is not being used for the upper 9-mile source control interim remedy feasibility study.

2 Overview of Modeling Framework

A suite of coupled models was developed to simulate the important processes affecting contaminant movement in the Lower Passaic River (LPR) in support of the LPRSA RI/FS. The modeling framework comprises five individual models: an HD model, an ST model, an OC model, a CFT model, and a bioaccumulation model. Together these models simulate contaminant movement and bioaccumulation in fish and crab tissue for the LPR and, through parameterization and calibration, provide predictions that reasonably match measured data.

Several of the modeling components were originally developed by USEPA, based in part on the model suite previously developed for the Contaminant Assessment and Reduction Project (CARP) of the New York/New Jersey Harbor Estuary Program, and have been adapted during the course of the LPRSA RI/FS. The models are subject to the requirements of the May 2007 Settlement Agreement and Order on Consent and Statement of Work (USEPA 2007) as well as the modeling work plan developed by the USEPA (HQI 2006a, 2006b). The modifications and calibrations of these have been performed under USEPA oversight, and the current level of accuracy in the HD, ST, OC, and CFT models has been deemed acceptable by USEPA for use in the FS (USEPA 2019). However, USEPA has noted that a "high degree of caution should be applied when using those predictions to compare remedial alternatives" given the uncertainties of modeling this complex system and the limits that these uncertainties and data gaps place on the accuracy of models' predictions.

The bioaccumulation model is currently undergoing calibration and USEPA review and is thus not part of the modeling framework for the IR FS evaluations presented in this appendix. A brief description of the HD, ST, OC, and CFT models used for the IR FS is provided below along with some discussion of model uncertainty and limitations. These models will be refined at a later time using data collected during the remedial design and improved spatial resolution.

2.1 Hydrodynamic Model

The HD model describes flow within the LPR, the adjacent Newark Bay Study Area, the Hackensack River, Kill van Kull, and Arthur Kill. It was developed using the Estuarine Coastal Ocean Model (ECOM; Blumberg and Mellor 1980, 1987) and is built upon the model developed by HDR|HydroQual (HQI; HQI 2008) and accepted by USEPA.

The original HD model development by HQI (2008) was calibrated for LPR and Newark Bay between 1995 and 2004. The LPRSA CPG modeling team then conducted extensive tests and additional model validation using LPR RI/FS datasets (e.g., the physical water column monitoring data collected in 2009 and 2010) and extended the simulation to cover 1995 through 2013. Under USEPA oversight, the CPG also refined some aspects of the model, including an update to the model's input

bathymetry to better represent the geometry of the LPR and the development of a truncated model grid suitable for use in LPR RI/FS simulations.

The HD model calculates the spatial and temporal distribution of flow velocity, water depth, temperature, salinity, horizontal and vertical turbulent mixing, and bottom shear stress, and passes this information to the ST, OC, and CFT models. Additional details on the HD model and its development are provided in Section 7 and Appendix L of the RI report (Anchor QEA et al. 2019).

2.2 Sediment Transport Model

The ST model incorporates the flows calculated by the HD model, and it calculates the erosion, deposition, and transport of sediments within the LPR and Newark Bay Study Area. The ST model framework is the same one used by USEPA in the Focused Feasibility Study (FFS; LBG 2014) and the March 2016 Record of Decision for the Lower 8.3 Miles (USEPA 2016). It started from the ECOM-SEDZLJS model, which applied the SEDZLJ algorithm by Jones and Lick (2000) within the computation framework of the ECOM hydrodynamic model, and it was later integrated with a bed consolidation model developed by Sanford (2008) by USEPA.

Under USEPA oversight, this ST model was further modified by the CPG to include a sediment fluff layer (i.e., a thin, easily erodible sediment layer overlying less erodible parent bed layers) and the erosion and suspended sediment loading due to navigation scour in selected portions of the LPR. The ST model includes two cohesive classes (clay and silt) and three non-cohesive classes (fine-medium sand, coarse sand, and gravel). The ST model was applied to the 1995 through 2013 period, covering discharge conditions ranging from low-flow conditions to an extreme event (Hurricane Irene, a 1-in-90-year storm event).

The ST model was calibrated and validated to a number of datasets, including suspended solids concentrations and solids fluxes measured as part of the physical water column monitoring program, suspended solids concentrations measured during the 2011 to 2013 chemical water column monitoring program and during extreme high-flow conditions, and short-term bathymetric changes between periodic bathymetric surveys conducted as part of the LPR RI/FS. The ST model was also shown to qualitatively reproduce infilling following the 1949 dredging within the lower 8 miles of the LPR (quantitative comparisons to long-term bed elevation changes were less favorable but are influenced by uncertainty in the historical boundary conditions and initial bathymetry, as well as related run simplifications).

Additional details on the ST model and its development are provided in Section 7 and Appendix M of the RI report (Anchor QEA et al. 2019).

2.3 Organic Carbon Model

The CPG OC model incorporates the results of the HD and ST models together with carbon boundary loadings to simulate the fate and transport of two carbon fractions in the water column: algae-associated (or biotic) carbon and sediment-bound detrital (or abiotic) carbon. Algae-associated carbon enters at the boundaries, but growth and respiration within the model domain (deemed as secondary importance to the overall fate and transport of algae-associated carbon) are not simulated. Algae-associated carbon is subject to settling and deposition to the bed. Detrital carbon is assumed to be associated with only the cohesive fraction of sediments (clays and silts) and subject to bed-water exchange via resuspension and deposition.

CPG's OC model is a USEPA-approved simplification of the full eutrophication model (Sediment Transport-System Wide Eutrophication Model [ST-SWEM]) originally proposed by the USEPA Region 2 (HQI 2006a) and applied in the FFS (LBG 2014). Comparisons of CPG's OC model predictions to measurements have indicated a reasonable model and data agreement. Some differences occurred primarily in the concentrations of algal carbon during summer months, likely due to the exclusion of algal growth in the model; however, these differences were demonstrated to have a nominal impact on associated CFT model test simulations.

Additional details on the OC model and its development are provided in Section 7 and Appendix N of the RI report (Anchor QEA et al. 2019).

2.4 Contaminant Fate and Transport Model

The CFT model calculates contaminant concentrations in the sediment and overlying water column based on the predicted spatial and temporal dynamics of flow, sediments, and carbon. It has been built using the RCATOX modeling framework developed by HQI, which was previously applied by USEPA to the LPR as part of the regional CARP model of the New York/New Jersey Harbor Estuary (HQI 2007) and on a finer scale in the FFS (LBG 2014; USEPA 2016).

Under USEPA oversight, the RCATOX framework and parameterization were modified by the CPG to use the same grid resolution as the HD, ST, and OC models, and reflect several additional processes including a sediment fluff layer to better represent the intra-tidal contaminant erosion and deposition fluxes, a kinetic sorption framework to account for resistantly sorbed chemical so as to better represent desorption from resuspended sediments, navigation scour to be consistent with the ST model, and a revised cohesive erosion velocity formulation to better represent the impact of vertical gradients in sediment composition on the erosion flux of contaminants.

The CFT model has been calibrated primarily for 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), tetrachlorobiphenyl (tetra-CB), and 1,2,3,4,6,7,8-HpCDF, and supplemented by the following six chemicals: 1,2,3,7,8-PeCDD, 2,3,4,7,8-PeCDF, PCB-126, PCB-167, total 4,4'-DDx (i.e., sum of 4,4'

isomers only), and mercury. The calibration was performed jointly to the water column data from the Chemical Water Column Monitoring program and to surface sediment data collected between 2005 and 2013.

Additional details on the CFT model and its calibration are provided in Section 7 and Appendix O of the RI report (Anchor QEA et al. 2019).

2.5 Model Uncertainty and Limitation

The LPR models represent state-of-the-science models that have been constructed with a wealth of data and a system understanding developed by USEPA and CPG over the course of the RI. The models capture the major characteristics of contaminant transport and are suitable tools to provide limited support to the development of an IR for the upper 9 miles and the associated FS. However, the models are subject to uncertainties and limitations that should be recognized and considered during the FS evaluation. As discussed in detail in Section 7.3.1 of the RI report (Anchor QEA et al. 2019), part of the model uncertainty comes from representing complex physical and chemical processes using simple mathematical equations or characterizing spatially and temporally variable system properties with constant parameters. Even though the models are calibrated, an additional part of the uncertainty is associated with the limitation on available data to establish plausible boundary conditions (BCs) and initial conditions (ICs) as well as to assess long-term changes of sediment and water column concentrations during the model calibration.

The uncertainty is also due to the relatively coarse spatial resolution of the models. To achieve run times that allow thorough model testing, calibration, and long-term projection of future conditions, the model coarsely represents the river, with three grid elements laterally and 62 grid elements longitudinally between river mile (RM) 8.3 and RM 15. As a result, smaller-scale bathymetric features affecting local shear stress and sediment erodibility are not represented, and the variability in erosion and deposition are dampened, which precludes the model from replicating some spatial patterns evident when comparing finer scale bathymetric surveys. The coarse grid resolution introduces additional uncertainty when simulating remedial alternatives with removal areas that are of smaller scale than the grid cells, as is the case in the IR FS active alternatives. Because model grid cells typically cover areas both within and outside of the remedial footprint, it is not possible to accurately represent the change in bed properties that occur when a remediated area is capped, and the concentration reduction associated with partial cell remediation must be parameterized. Details about the approaches used to simulate sub-grid scale remedial targets are provided in Section 3.

Another source of uncertainty in simulating remediation is the amount of solids and contaminants released to the water column during construction. This process was parameterized in the model simulations as a lumped dredge resuspension loss rate (the fraction of the total mass removal rate lost to the water column during dredging), which represents the combined effect of sediment

resuspended due to the dredge bucket disturbing the bed, sediment lost to the water column from the bucket, and exposed subsurface sediment that is mobilized before being sequestered by capping (i.e., "generated residuals"). The rate of dredge resuspension could vary due to factors such as the technology used, the type of dredged sediments (grain size, debris, etc.), and the hydrodynamic conditions. Two dredge resuspension rates were simulated as part of the IR FS projections, as discussed in Section 3.

Model projections have additional uncertainty that is derived from uncertainties associated with other parameters and assumed conditions. Notable among these are the sequence of low and high flows in the hydrograph, and the dredging sequence. These uncertainties were not formally evaluated, but diagnostic runs of the model not shown here have illustrated their importance and signify that the uncertainty considered in the FS underrepresents the true uncertainty of the projections. A related uncertainty is the contaminant boundary loading to the system in the post-remedy period, which has the potential to exert a larger influence on contaminant levels within the LPR once the in-river contaminant sources have been reduced by remediation.

The models also exhibit two notable biases discussed in Section 7.3.2 of the RI report (Anchor QEA et al. 2019). The ST model does not accurately distinguish erosion and deposition on the established grid scale and tends to calculate net erosion rates that are lower than those inferred from differences between some of the RI bathymetric surveys (most notably the 2008 to 2010 period, which includes the March 2010 16,000 cubic feet per second [cfs] flow event). The CFT model overestimates long-term reductions in surface sediment COC concentrations (water year [WY] 1996 to WY2009) in net depositional areas between RM 1 and RM 7. These limitations are likely to be largely due to the relatively coarse grid resolution discussed above, which prevents finer-scale details of the river morphology from being represented. Therefore, the limited accuracy of the current models' predictions of erosion and deposition and of COC concentration reduction over time should be considered when making regulatory decisions for the LPR. Nonetheless, the models were deemed suitable to support comparative evaluations among alternatives (USEPA 2019). In doing so, projected concentrations and rates of recovery will be expressed as ranges rather than absolute values (CPG 2019).

3 Projection Modeling Approach

Model projections were performed to evaluate future conditions under the No Action (NA) alternative (Alternative 1) and the four active remedial alternatives defined by their post-remedy 2,3,7,8-TCDD surface area-weighted average concentration (SWAC) targets: 85, 75, 65, and 125 nanograms per kilogram (ng/kg; Alternatives 2, 3, 4, and 5, respectively). The COCs simulated are 2,3,7,8-TCDD and tetra-CB, which is used as a surrogate for total polychlorinated biphenyls [PCBs].

Twenty-two projections were performed for each COC (Table 1) to evaluate the alternatives and characterize the sensitivity to three sources of uncertainty. These include the following runs:

- Eighteen projections were performed using sediment ICs and remedial footprints based on the Conditional Simulation (CS) 37 base map[2]; these form a basis for the comparison of alternatives in Section 8 of the main report. In recognition of two major sources of uncertainty, four projections were conducted for each alternative. Two dredge resuspension rates (3% and 1%)[3] were paired with two approaches to representing the remediation in the HD, ST, and OC sub-models. These approaches are termed "MNR ST" (Monitored Natural Recovery ST) and "Scenario-specific ST", and are described below. The uncertainty bands considered in the FS comparison of alternatives are based on this suite of projections.
- Four projections were performed using sediment ICs and remedial footprints derived from two alternate CS maps (CS 57 and CS 81) and the two approaches to represent remediation (MNR ST and Scenario-specific ST). These projections were limited to Alternative 3 with a 3% dredge resuspension loss rate. They demonstrated that projections of remedial benefit are not greatly altered by the choice of concentration map. On this basis and in the interest of limiting the modeling effort, mapping uncertainty was not propagated to all alternatives.

Details of the projection modeling approach are provided below. Section 3.1 describes the representation of future conditions and Section 3.2 describes the representation of active remediation. Section 3.3 describes the approach to converting tetra-CB predictions to total PCB predictions.

3.1 Representation of Future Conditions

All alternatives (including the NA alternative) include implementation of the Record of Decision (ROD) remedy in the lower 8 miles of the LPR. Projection simulations were run for 18 years,

[2] As described in Appendix B, contaminant mapping of the LPR sediment bed was performed using conditional simulation to account for the uncertainty arising from interpolation of sparse sediment data by generating 100 equally probable realizations of the concentration map. One of these maps, CS 37, was selected as a central tendency base map and used for most evaluations presented in the main FS report.

[3] A 3% dredge resuspension rate was evaluated for consistency with prior USEPA simulations of the ROD remedy in the lower 8 miles, per USEPA direction. The CPG believes a lower rate can be achieved in the IR, and consequently evaluations of a 1% dredge resuspension rate were added (with USEPA consent).

beginning from the first year of the ROD remedy[4] and running 10 years beyond completion of the largest IR alternative. The WY1996 to WY2010 hydrograph was applied and cycled as shown in Table 2.

The ICs for the IR FS projection simulations were set as follows:

- The predicted bathymetry at the end of the CPG LPRSA HD/ST model calibration period (WY1996 to WY2013), which includes the post 50-foot deepening bathymetry in Newark Bay and the Kills, defined the initial bathymetry for the projection runs. Specifically, it was used to initialize the IR FS ST model spin-up run described below.
- The IR FS ST model initial bed properties (i.e., bed composition and bulk density) and water column suspended sediment concentrations were based on a 1-year spin-up run performed with the WY1995 hydrograph and the bed properties at the beginning of the WY1996 to WY2013 ST model calibration run (see Appendix M of the RI report [Anchor QEA et al. 2019]), except for grid cells that were remediated during the calibration simulation which are treated as follows:
  - Grid cell (16,127) is associated with the Phase 1 removal action; it was remediated at the beginning of WY2012 and then simulated through the end of WY2013. The properties from the end of the CPG LPRSA ST calibration were used for this cell in all IR FS model simulations.
  - Grid cells (18,189), (18, 190), and (18, 191) are associated with the RM 10.9 time critical removal action and were assigned cap properties in the IR FS ST runs that represent capping in the upper 9 miles (i.e., in the "Scenario-specific" ST uncertainty runs described below). These bed properties (see Table 3, third row) were imposed at the start of the 1-year spin-up run that precedes the IR FS ST projection runs.
- The IR FS OC model initial bed carbon concentrations were specified in a manner similar to the WY1996 to WY2013 calibration period, i.e., the predicted cohesive sediment fraction in the bed at the end of the IR FS ST model spin-up run was combined with the data-based relationship between fraction organic carbon (foc) and cohesive sediment fraction developed in Appendix N of the RI report (Anchor QEA et al. 2019). The initial bed carbon concentrations in the grid cells associated with the Phase 1 removal action and RM 10.9 time critical removal action (see prior bullet for the grid cell IDs) were specified in the same manner, i.e., by applying the relationship between foc and cohesive sediment fraction to the ST model's bed composition for these cells.
- The IR FS CFT model initial sediment contaminant concentrations were based on the "2010" mapping (see Appendix J of the RI report [Anchor QEA et al. 2019]), which combines CS results in the surface sediments (0- to 0.5-foot interval) with a resampling method in the 0.5-

[4] Per USEPA direction, the ROD remedy start date was assumed to be July 1, 2021.

to 1.5-foot interval and Thiessen polygons beneath that. The CS based mapping (CS 37, 57, or 81; Table 1) was used to set concentrations in the surface sediments for all cells (using the area-weighted mean) with the exception of the following:

- The grid cells associated with the RM 10.9 time critical removal action, where the concentrations were specified as the area-weighted mean of the CS based mapped concentrations outside of the removal footprint and an average concentration from post-remedy monitoring data[5] within the removal footprint
- The grid cell associated with the Phase 1 removal area, which was assigned the contaminant concentrations from the end of WY2013 of the CPG LPRSA long-term CFT calibration

The vertical distribution of contaminant within the near-surface sediments was for all cells based on the shape extracted at the end of WY2010 of the CPG LPRSA long-term calibration simulation using the approach described in Appendix O of the RI report (Section 3; Anchor QEA et al. 2019).

The projection BCs were determined based on the applied hydrograph (WY1996 to WY2010, cycled as shown in Table 2) and an assumed start date of 2021 for the ROD remedy. A year-by-year comparison of the USEPA FFS model hydrograph and the IR FS model hydrograph is provided in Table 2. Projection BCs were set as follows:

- IR FS hydrodynamic model inflow BCs at Dundee Dam and tributaries as well as meteorological forcing (wind stress and heat flux) were repeated from the calibration period in accordance with the cycling of the WY1996 to WY2010 hydrograph (i.e., BCs for WY1996 are used for projection years 1 and 16). The hydrodynamic BCs at the Kill van Kull and Arthur Kill open boundaries for all years were based on simulation results of the regional USEPA LPRSA model, which included post-harbor-deepening bathymetry in Newark Bay and the Kills, as provided by USEPA and consistent with the FFS model. Specifically, the FFS model BC sequence from 2014 onward was used because this year corresponds to the WY1996 in the FFS model projections (see Table 2).
- Solids, carbon (detrital and algal), and contaminant loads from the Dundee Dam, tributaries to the LPR, the Hackensack River, point and nonpoint sources (wastewater treatment plants and combined sewer overflows/stormwater outfalls), and atmospheric loadings (contaminants only) were also the same as for the corresponding calibration hydrograph years.
- For the Kills boundary, solids concentrations were based (as in the calibration) on the predicted tidal velocities and water surface elevations at the boundaries paired with a solids

[5] For 2,3,7,8-TCDD, a mean value of 227 nanograms per kilogram (ng/kg) was applied to remediated areas based on the 16 available 2015 Environmental Response Team and 2016 CPG post-remedy cap monitoring data points. For tetra-CB, a mean value of 0.15 milligrams per kilogram was applied based on the 2015 Environmental Response Team data only (six samples) because the CPG dataset did not report tetra-CB.

loading relationship under the post-deepening bathymetry (see Appendix M of the RI report [Anchor QEA et al. 2019]). The Kills boundary carbon and contaminant concentrations were based on the output from simulations of the regional CARP model, consistent with USEPA's FFS model. Specifically, the USEPA FFS model projection BC sequence starting in WY2014 was used for the carbon concentrations, consistent with the hydrodynamic BCs in the IR FS model. For contaminant concentrations at the Kills, the USEPA FFS model BC sequence starting in WY2021 was used to reflect the concentration trend predicted by the CARP model to occur prior to the start of the ROD remedy in 2021. Furthermore, tetra-CB concentrations from the Kills boundary were reduced by half to be consistent with the boundary settings in the CPG LPRSA CFT model calibration (see Appendix O of the RI report [Anchor QEA et al. 2019]).

During the projection run, the bathymetry in the IR FS HD/ST models in the active Newark Bay, Kill van Kull, and Arthur Kill navigational channels were reset to the 50-foot design depth every 5 years (starting from the end of projection year 5) to represent maintenance dredging.

3.2 Simulation of Active Remediation

The representation of active remediation is described separately for the ROD remedy for the lower 8.3 miles and the IR alternatives for RM 8.3 to RM 15 because the latter footprints required a modified approach to accommodate the finer scale of the remediation (i.e., partial grid cell remediation must be represented).

3.2.1 Representation of the ROD Remedy for the Lower 8.3 Miles

The ROD remedy in the lower 8.3 miles was simulated in a manner consistent with USEPA's FFS modeling (see LBG 2014; USEPA 2016). The FFS dredge sequence was used[6], updated to include the Tierra Phase 2 Removal areas as part of the ROD remedy (per USEPA direction) and applied starting in Year 1 of the projections (see Table 2). The bed elevations in the IR FS HD model were updated daily in remediated cells to gradually impose the bathymetric change resulting from dredging (dredging followed by capping back to grade in all areas except for within the navigational channel in the lower 2 miles, where, per the ROD, the LPR will be deepened in conjunction with the remedy and thus capped but not back to grade). The sediment composition in remediated cells was adjusted in the IR FS ST model to reflect the cap material, using the bed properties in Table 3 for consistency with USEPA's FFS model. The bed foc in the OC model in capped areas was calculated from the cap composition, assuming 10% OC on cohesive particles (size classes 1a, 1b, 2a, and 2b) and no OC on the remaining size classes, consistent with the FFS model assumption. The contaminant concentrations of the CFT model bed (active and archive layers) in remediated areas were set to zero.

[6] The capping schedule was inadvertently shifted to occur 2 to 6 days ahead of the ROD remedy sequence for the following cells at Kearny Shoal: (18,97), (18,96), (19,97), (19,96), (18,95), and (18,94). This shift was deemed to have no material impact to the IR FS evaluation, and consequently no further changes to the dredge schedule were made.

The dredge resuspension loss (3% or 1% depending on the simulation; Table 1) was applied to release sediment, carbon, and contaminant mass to the water column, distributed equally between the top and bottom layers of the water column. Note that the ROD remedy is included in all alternatives, including Alternative 1 (the NA alternative).

3.2.2 Representation of the IR Alternatives

The development of the IR remedial footprints is described in Section 7 of the main report and Appendix B. The remedial footprints and volumes for each alternative were mapped to the model grid, and the dredge sequence and duration for each model grid cell were determined based on the assumed production rate. As previously described, the projections supporting the comparison of alternatives in Section 8 of the main report used sediment ICs and remedial footprints based on the CS 37 base maps (Projections 1 to 18 in Table 1), while the four projections used to characterize the impact of mapping uncertainty used sediment ICs and remedial footprints from CS 57 and CS 81 (Projections 19 to 22 in Table 1). These latter two maps were selected on the expectation that they yield higher recovery (CS 57) and lower recovery (CS 81) during the IR, based on CPG and USEPA evaluations of the covariance of the concentration field with erosion and deposition patterns (see Appendix B for further details on the selection of these maps).

The impact of partial grid cell remediation on bed concentrations was parameterized in the CFT model based on the mapping and associated footprint delineations (see Section 3.2.2.1 for details). In the ST model, the impact of partial cell remediation on sediment transport cannot be accurately represented in an analogous manner because the relationship between grain size and sediment erodibility is non-linear (i.e., the change in average erodibility across remediated and unremediated portions of a partially capped cell cannot be represented by a simple adjustment of grain size). Recognizing this limitation, the projections were simulated with dual approaches to representing the remedial alternatives in the IR FS HD, ST, and OC models:

- In the "MNR ST" projection runs (Projections 1 to 5, 10 to 14, and 19 to 20 in Table 1), IR remediation was not represented in the HD, ST, and OC models. Rather, the CFT model was run using HD, ST, and OC model results from the NA alternative (Alternative 1). By not simulating the remedy in the ST model, this set of runs ignores the effects of IR capping on bed grain size and erodibility and the release of solids to the water column associated with IR dredging resuspension. Likewise, the influence of water column carbon release due to IR dredging and bed carbon adjustments due to IR capping was ignored by not representing the remedy in the OC model (this was done for consistency with the ST model treatment). These processes were still represented in the lower 8.3 miles, where partial grid cell remediation is not an issue because the ROD remedy footprint is bank-to-bank.
- In the "Scenario-specific ST" projection runs (Projections 6 to 9, 15 to 18, and 21 to 22 in Table 1), the influence of capping on the bed texture and the solids and carbon release on the water

column was represented in the HD, ST, and OC models as if the entire cell was capped (i.e., including the portion not remediated). The approach described in Section 3.2.2.2.

The IR remedy representation within the IR FS ST, OC, and CFT models in the projection runs is summarized in Table 4[7].

3.2.2.1 Representation of IR Alternatives in the CFT Model

The CFT model bed concentration for a given cell was, at the time of remediation, multiplied by a reduction factor that reflects the ratio of the grid cell average post-dredge concentration in the 2010 mapping (i.e., after the concentrations in targeted areas have been reset to zero[8]) to the grid cell average pre-dredge concentration. The reduction factors[9] (alternately "dredge ratios") are COC-specific and were computed for each data layer considered in the mapping (i.e., 0- to 0.5-foot, 0.5- to 1.5-feet, 1.5- to 2.5-feet, 2.5- to 3.5-feet, and 3.5- to 5.5-feet)[10] based on the typical sediment core segmentation. The dredge resuspension loss (3% or 1% of the contaminant mass removed, depending on the simulation) was released to the water column during dredging and distributed equally to the top and bottom water column grid layers, consistent with the representation in the lower 8.3 miles of the LPR (discussed above).

3.2.2.2 Representation of IR Alternatives in the HD, ST, and OC Models

The "scenario-specific" HD, ST, and OC model runs represent the temporary bathymetric adjustments due to dredging and subsequent capping, the release of solids and OC to the water column during dredging, and changes to the surface sediment bed properties caused by capping. Due to the previously noted limitations of representing sub-grid scale capping, changes in bed properties due to capping can only be made on a whole cell basis. As a compromise, cells with more than 50% remediated area were capped in the ST and OC models, with cap composition set to "Core ID 38" (from the USEPA FFS model) as described in Table 3. The dredging-associated solids and carbon release to the water column were simulated for all cells with remediation, as grid scale limitations do not prevent the representation of this process.

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[7] The HD model is not included in Table 4 for simplicity. There is a unique HD model run corresponding to each ST model run, thereby accounting for the effects of bathymetry changes on the circulation and bottom shear stresses.

[8] Although the underlying footprints were developed by assuming a 10 ng/kg residual concentration of 2,3,7,8-TCDD when conducting the hill-topping to achieve a given alternative's target SWAC (see FS Appendix B), a zero residual concentration is assumed in calculating the concentration reduction factors for model input. This is done because the model explicitly accounts for recontamination due to resuspension during the dredging and other contaminant sources.

[9] This is mathematically equivalent to assigning a weighted average of zero concentration in the remediated portion and the mapped concentration in the unremediated portion, adjusted by the predicted fractional change of the grid cell concentration from its IC to the time of remediation, as discussed in past USEPA and CPG modeling meetings.

[10] Sediment contaminant concentrations below 2.5 feet were also adjusted to reflect the remedial footprint despite these intervals being below the anticipated dredge depth. For remedial areas that are not capped in the model due to grid resolution limitations (described previously), the model projections do not account for the sequestering of contaminant below the dredge depth by the cap, and if subsurface contaminant concentrations were left unadjusted, they could corrupt the projection by impacting the surface sediment concentrations.

Note that the RM 10.9 time critical removal action in 2013 is considered a partial cell remediation similar to the proposed IR remediation. For consistency, dredging and capping were not represented in the RM 10.9 time critical removal area in the MNR ST based projections, and the 50% area rule was extended to the RM 10.9 time critical removal area for the Scenario-specific ST based projections.

3.3 Estimation of Total PCBs from Tetra-CB

Total PCBs are estimated using model predicted tetra-CB results and correlations between total PCBs and tetra-CB from empirical data collected during the RI. For the surface sediment SWAC, a piecewise linear regression was applied which yields the best fit across the full concentration range (Figure 1). For the water column-related metrics (i.e., the water column concentrations, downstream loads and the concentration on depositing fine sediments), a single linear regression with zero intercept was used[11] (Figure 2). For the gross and net erosion fluxes, a single linear sediment regression with zero intercept was used (Figure 3) because the concentration dependence of the piecewise regressions in Figure 1 cannot be accurately applied to the flux. Although the relationship between net erosion flux of tetra-CB and total PCBs may in reality reflect some combination of the regressions based on water column and sediment data, for simplicity a separate conversion for net erosion flux was not pursued, recognizing that this approximation is unlikely to have a material impact to the comparison of alternatives. Table 5 summarizes the equations used to estimate total PCBs from tetra-CB predictions; these relationships were applied on a grid cell level prior to spatial averaging.

[11] A piecewise linear regression was also developed for the water column (analogous to the one for the sediment), but it was not used because the non-zero intercepts of the higher concentration range regressions prevent the conversion of average tetra-CB load to average total PCB load. The correlation coefficient from the single regression is the same as that of the piecewise regression (R^2 =0.97).

4 Projection Results

The results shown in Section 8 of the main FS report are presented as ranges in accordance with the modeling guidelines described in Section 6.2 of the main FS report and in CPG (2019). The corresponding model metrics from the 18 individual projection simulations used in Section 8 of the main FS report are presented below in Section 4.1, focusing on the RM 8.3 and RM 15 IR region. Results from the last four projections (i.e., Projections 19 to 22 in Table 1) are presented in Section 4.2 to characterize the uncertainty due to mapping (see overview provided in Section 3). Lastly, additional details on the estimated SWAC recovery half-lives, one of the source control metrics evaluated in the comparison of alternatives, are provided below in Section 4.3.

It is noted that irregularities in some projections were noted during detailed quality control reviews. Most were corrected and the ones that remain are minor and summarized in Table 6. Those unaddressed, as noted in Table 6, do not have a material impact on the comparative evaluation of the alternatives even though some are discernable in figures presented in this FS.

4.1 Projection Results Used in the Comparison of IR Alternatives

Model results for the active IR alternatives, Alternatives 2 through 5, were presented as ranges based on four projections capturing uncertainties associated with dredge resuspension and the representation of remediation in the HD, ST, and OC models. As described in Section 3, these include the following:

- MNR ST remedy representation with a 3% dredge resuspension loss rate
- MNR ST remedy representation with a 1% dredge resuspension loss rate
- Scenario-specific ST remedy representation with a 3% dredge resuspension loss rate
- Scenario-specific ST remedy representation with a 1% dredge resuspension loss rate

For Alternative 1 (NA), the range of model results was based on projections with the first two run configurations listed above (dredge resuspension is relevant to Alternative 1 also because it includes remediation in the lower river).

Figures 4 through 9 present time-series[12] of 2,3,7,8-TCDD and total PCB predictions for Alternatives 2 through 5 for select metrics employed in the comparison of alternatives in Section 8 of the main FS report. Results from each of the four projection configurations listed above are shown alongside the Alternative 1 projections (for reference). The following metrics are presented for 2,3,7,8-TCDD and total PCBs for the full 18-year projection period:

- SWAC in RM 8.3 to RM 15 (Figure 4a and 4b)
- Average water column concentration in RM 8.3 to RM 15 (Figures 5a and 5b)

[12] Note that the figure legends employ the term "Remedy ST" when referencing the Scenario-specific ST runs. These terms are synonymous.

- Cumulative water column downstream load at RM 8.3 (Figures 6a and 6b)
- Gross erosion flux in RM 8.3 to RM 15 (Figures 7a and 7b)
- Net erosion flux in RM 8.3 to RM 15 (Figures 8a and 8b)
- Concentration on depositing fine sediments in RM 8.3 to RM 15 (Figures (9a and 9b)

The figures are based on daily output frequency for SWAC and downstream load, whereas monthly averages are used for the remaining variables to smooth the variability. The average concentration on depositing fine sediment is calculated as the ratio of the total contaminant deposition flux to the total fine sediment deposition flux, where each quantity is accumulated monthly before taking the ratio.[13]

The sensitivity of the model results to the two sources of uncertainty explicitly considered in the projections listed above are discussed below. It is noted that generally the model sensitivity for these metrics is greater for 2,3,7,8-TCDD than it is for total PCBs, due to the upstream boundary influence of PCBs. This yields a smaller uncertainty band for total PCBs in the comparison of alternatives, but this result should not be taken to mean that the uncertainty for PCBs is necessarily less because the runs do not evaluate the potential contribution of boundary condition uncertainty to the predictions and this will have a larger influence on PCBs than 2,3,7,8-TCDD.

4.1.1 Model Sensitivity to Dredge Resuspension Loss Rate

The influence of the assumed dredge resuspension loss rate on the RM 8.3 to RM 15 SWAC is most evident when the IR construction is complete in Year 7 for Alternative 5 and in Year 8 for Alternatives 2, 3 and 4 (Figure 4a and 4b, comparing red and blue lines for Alternatives 2 through 5). Over the post-IR period spanning Year 9 through Year 18, the upper and lower bound SWACs for both 2,3,7,8-TCDD and total PCBs correspond to the runs with 3% dredge resuspension and 1% dredge resuspension, respectively (this is true for either remedy representation in the ST model, the effect of which is discussed in the next section). At the start of Year 9 (i.e., the start of the post-remedy period used in the comparison of alternatives), the initial difference in SWAC is about 20% to 50% and the results converge by the end of the projection to yield about a 3% to 11% difference for 2,3,7,8-TCDD and a 0.2% to 3% difference for total PCBs.

The RM 8.3 to RM 15 average water column concentration of 2,3,7,8-TCDD and total PCBs (Figures 5a and 5b) and the downstream load at RM 8.3 (Figures 6a and 6b) predicted in the 3% dredge resuspension runs are higher than in the corresponding 1% dredge resuspension runs during the IR construction period (Years 4 to 8). These concentration differences persist for 2,3,7,8-TCDD for the

[13] The ratio of total chemical flux to total fine sediment flux is used because it is more representative of what the sediment bed experiences over time than the time-averaged ratio of the deposition fluxes, as the latter would be influenced by periods of low sediment deposition. In Figures 9a and 9b, the ratio of monthly fluxes was used. For the corresponding metric in Figure 8-27 of the main FS report, the ratio of annual fluxes was used in the top panel and the ratio of 10-year post-IR fluxes was used for the middle panel, i.e., the averaging period was tailored to the period of interest.

first few years after IR completion and then converge, analogous to the SWAC uncertainty band discussed above. The post-IR concentrations are more similar for total PCBs, reflecting the larger influence of the upstream loading of PCBs. The cumulative downstream loads of 2,3,7,8-TCDD and total PCBs at RM 8.3 (Figures 6a and 6b) reflect the differences noted for water column concentration, with higher loads for the 3% dredge resuspension runs during the IR construction period and more similar loads in the post-IR period (Years 9 through 18). The latter is indicated by the similarity of the slopes of the 3% and 1% cumulative loads post-IR, particularly for total PCBs.

The remaining three metrics are all measures of source control: gross erosion flux (Figures 7a and 7b), net erosion flux (Figures 8a and 8b), and concentration on depositing fine sediment (Figures 9a and 9b). These metrics largely track the patterns noted above for the water column concentration and loads, perhaps not surprising given the dependence of water column concentration on erosion flux and the feedback of these concentrations on depositing particle concentrations. Likewise, the influence of resuspension is less notable on total PCBs than on 2,3,7,8-TCDD due to the stronger upstream loading influence of the former.

4.1.2 Model Sensitivity to Remedy Representation in the ST Model

RM 8.3 to RM 15 post-IR SWACs are projected to be lower in the Scenario-specific ST runs relative to the corresponding MNR ST runs (this is true for either dredge resuspension rate assumption; see Figures 4a and 4b, comparing solid lines to dashed lines for Alternatives 2 through 5). These projection results tend to converge somewhat over time, although the convergence is not as great as between the 3% and 1% dredge resuspension runs under either remedy representation.

The lower SWAC in the scenario-specific runs is attributed to several factors, which include the following:

- Recontamination on capped cells is less likely due to the higher bottom shear stresses acting on the grains (skin friction) over the rougher bottom which reduces net sediment deposition.
- The inclusion of sediment releases into the water column due to dredge resuspension on average dilutes the CFT model's particulate concentrations in the water column.
- The Scenario-specific ST runs show less uptick during high flow events post-remedy because erosion is reduced by capping, and this influences even the contaminant mass in unremediated portion of capped cells (i.e., cells with more than 50% area remediated, as described in Section 3.2).
- Within the capped grid cells, dry-weight concentrations in unremediated areas are also subject to an artificial dilution due to the normalization of the predicted volumetric concentrations by the higher cap bulk density.

The influence of the remedy representation on the other metrics in Figures 5 through 9 is less visible than it is for SWAC, and the divergence between Scenario-specific ST and MNR ST is likewise less than the divergence due to the dredge resuspension assumption.

4.2 Projection Results on Mapping Uncertainty

Projection results for Alternative 3 using CS 57 and CS 81 maps (see Projections 19 through 22 in Table 1) are compared with the corresponding runs using CS 37 map to assess the uncertainty of model projections to map selection and the resulting remedial footprints. The results are presented in Figures 10 through 12 for a subset of model metrics:

- Surface Sediment SWAC in RM 8.3 to RM 15 (Figure 10a and 10b)
- Water Column Concentration in RM 8.3 to RM 15 (Figure 11a and 11b)
- Cumulative Water Column Downstream Load at RM 8.3 (Figure 12a and 12b)

As described in Section 3, these alternate contaminant maps were evaluated only for a 3% dredge resuspension. The MNR ST results are plotted in the top panel and the Scenario-specific ST case is shown in the bottom panel.

The variations in the CS map results in different 2,3,7,8-TCDD and total PCB SWAC ICs at the start of Year 1 and this difference remains apparent during the IR construction period in Years 4 to 8 (Figure 10a and 10b). However, the variation in the SWACs is reduced upon completion of the remedy, which is consistent with expectations because the remedial footprints were delineated separately for each of the three maps and each delineation is designed to reach the 75 ng/kg SWAC target of Alternative 3. Similarly, the water column concentrations show some variation to the selection of contaminant map (Figures 11a and 11b) and these occur mostly during the IR construction period. The cumulative water column downstream load at RM 8.3 follows suit in that there is some deviation in the cumulative load between the three maps but most of these differences are due to the fluxes during the IR construction period (Figures 12a and 12b).

4.3 SWAC Recovery Half-life

The SWAC recovery half-life (i.e., the time to reduce SWAC by 50%) was employed in Section 8 of the main FS report as a metric of the relative effectiveness of alternatives at controlling sources and promoting long-term recovery of surface sediments. The recovery half-life was estimated by performing a log-linear regression of monthly-average RM 8.3 to RM 15 SWACs over the 10-year post-IR period spanning Years 9 through 18, and it was calculated relative to the SWAC at the beginning of Year 9 (Alternatives 2, 3, and 4 end at various times during Year 8 but for consistency the beginning of Year 9 was considered the start of the post-remedy period for this and other analyses presented in Section 8 of the main FS report). The evaluation is based on assuming that the recovery from the initial post-remedy SWAC follows a first order decay:

Equation 1

$$\frac{dC}{dt} = -kt$$

where:

C	=	SWAC (expressed in ng/kg for 2,3,7,8-TCDD or mg/kg for PCBs)
t	=	time since the start of the post-remedy period at the start of Year 9 (years)
k	=	first-order recovery rate (1/year)

This has the solution:

Equation 2

$$C = C_0 e^{-kt}$$

where:

C_0	=	the initial SWAC at the start of the post-remedy period (i.e., the SWAC at the end of year 8 for each simulation)

The recovery rate (k) may be estimated by log-linear regression:

Equation 3

$$ln\left({}^{C}/_{C_0}\right) = -kt$$

From which the recovery half-life ($t_{1/2}$) in years, i.e., the time to reach $C/C_0 = 0.5$, is defined as:

Equation 4

$$t_{1/2} = \frac{ln(2)}{k}$$

Table 7 presents the estimated recovery half-lives for the individual projection runs used in the comparison of alternatives and shown in Figure 8-12 of the main FS report, where they are presented as ranges in accordance with the modeling guidelines in Section 6.2 of the main FS report (see also

CPG [2019]). It is emphasized that these recovery half-lives are not model predictions; rather they are estimates derived from predictions. As such, they vary depending on the assumptions embedded in the analysis. The half-life estimates are best used qualitatively in the comparative analysis and are not a reliable means to quantify recovery beyond the simulated 10-year post-remedy period such as the time to reach a particular future SWAC, particularly considering the multiple source of uncertainty described in Section 2.5.

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Tables

Table 1
Summary of IR FS Projection Simulations

Projection Number	CS Map	Dredge Resuspension Loss rate	CFT Model Inputs*	HD/ST/OC Model Inputs
1	CS 37	3%	Alt 1 (NFA)	MNR
2	CS 37	3%	Alt 2 (85 ng/kg)	MNR
3	CS 37	3%	Alt 3 (75 ng/kg)	MNR
4	CS 37	3%	Alt 4 (65 ng/kg)	MNR
5	CS 37	3%	Alt 3 (125 ng/kg)	MNR
6	CS 37	3%	Alt 2 (85 ng/kg)	Scenario-specific
7	CS 37	3%	Alt 3 (75 ng/kg)	Scenario-specific
8	CS 37	3%	Alt 4 (65 ng/kg)	Scenario-specific
9	CS 37	3%	Alt 5 (125 ng/kg)	Scenario-specific
10	CS 37	1%	Alt 1 (NFA)	MNR
11	CS 37	1%	Alt 2 (85 ng/kg)	MNR
12	CS 37	1%	Alt 3 (75 ng/kg)	MNR
13	CS 37	1%	Alt 4 (65 ng/kg)	MNR
14	CS 37	1%	Alt 5 (125 ng/kg)	MNR
15	CS 37	1%	Alt 2 (85 ng/kg)	Scenario-specific
16	CS 37	1%	Alt 3 (75 ng/kg)	Scenario-specific
17	CS 37	1%	Alt 4 (65 ng/kg)	Scenario-specific
18	CS 37	1%	Alt 5 (125 ng/kg)	Scenario-specific
19	CS 57	3%	Alt 3 (75 ng/kg)	MNR
20	CS 81	3%	Alt 3 (75 ng/kg)	MNR
21	CS 57	3%	Alt 3 (75 ng/kg)	Scenario-specific
22	CS 81	3%	Alt 3 (75 ng/kg)	Scenario-specific

Note:
*Column entries refer to the remedial alternative that is the basis for the inputs, where concentrations refer to the 2,3,7,8-TCDD post-remedy SWAC target that defines the active alternatives.
Runs used in the comparison of alternatives in Section 8 of the main FS Report are shaded yellow.
Alt: alternative
CFT: contaminant fate and transport
CS: conditional simulation
FS: feasibility study
HD: hydrodynamic
IR: Interim Remedy
MNR: monitored natural recovery
NFA: no further action
ng/kg: nanogram per kilogram
OC: organic carbon
ST: sediment transport
SWAC: surface-weighted average concentration

Table 2
Comparison of the Hydrograph for the IR FS Projections and Hydrograph for the USEPA FFS Model Projections

USEPA FFS Model Water Year	USEPA FFS Simulation Hydrograph	CPG IR FS Model Water Year	CPG IR FS Simulation Hydrograph	Period Description
1995	1995	1995	1995	HD/ST model spin-up
1996	1996	1996	1996	Calibration period HD, ST, OC, CFT
1997	1997	1997	1997	
1998	1998	1998	1998	
1999	1999	1999	1999	
2000	2000	2000	2000	
2001	2001	2001	2001	
2002	2002	2002	2002	
2003	2003	2003	2003	
2004	2004	2004	2004	
2005	2005	2005	2005	
2006	2006	2006	2006	
2007	2007	2007	2007	
2008	2008	2008	2008	
2009	2009	2009	2009	
2010	2010	2010	2010	
2011	2011	2011	2011	
2012	2012	2012	2012	
2013	2013	2013	2013	
2014	1996	N/A	Not simulated	Pre-remedy period
2015	1997			
2016	1998			
2017	1999			
2018	2000			
2019	2001			
2020	2002	Spin-up (Year 0)	1995	HD/ST model spin-up in IR FS
2021	2003	Year 1*	1996	Lower 8.3 miles ROD remedy implementation USEPA FFS: WY2020 to WY2026 IR FS: Year 1 to Year 6 Upper 9 miles IR implementation IR FS: Year 4 to Year 8 (end date is alternative-specific)
2022	2004	Year 2	1997	
2023	2005	Year 3	1998	
2024	2006	Year 4	1999	
2025	2007	Year 5	2000	
2026	2008	Year 6	2001	
2027	2009	Year 7	2002	

USEPA FFS Model Water Year	USEPA FFS Simulation Hydrograph	CPG IR FS Model Water Year	CPG IR FS Simulation Hydrograph	Period Description
2028	2010	Year 8	2003	
2029	1996	Year 9	2004	Post-remedy period
2030	1997	Year 10	2005	
2031	1998	Year 11	2006	
2032	1999	Year 12	2007	
2033	2000	Year 13	2008	
2034	2001	Year 14	2009	
2035	2002	Year 15	2010	
2036	2003	Year 16	1996	
2037	2004	Year 17	1997	
2038	2005	Year 18	1998	

Notes:
*Year 1 of the CPG IR FS is matched to USEPA FFS Year 2021 per USEPA direction to assume a ROD remedy start date of July 1, 2021. Consequently, the IR FS simulations use the USEPA FFS model contaminant boundary condition sequence at the Kills from 2021 onwards.
Years shaded in yellow, orange, and gray indicate periods of model calibration, active remediation in the lower 8.3 miles or upper 9 miles, and model spin-up, respectively.
CFT: contaminant fate and transport
CPG: Cooperating Parties Group
CS: conditional simulation
FFS: focused feasibility study
FS: feasibility study
HD: hydrodynamic
IR: Interim Remedy
N/A: not applicable
OC: organic carbon
ROD: Record of Decision
ST: sediment transport
USEPA: U.S. Environmental Protection Agency
WY: water year

Table 3
Summary of Cap Properties Used in IR FS ST Model Projections

Cap Location*	ST Model Core ID	Critical Shear Stress, τ_{cr} (dynes/cm^2)	Fraction of ST Model Sediment Grain Size Class in Cap (%)						
			1a (d_{50} = 2 µm)	1b (d_{50} = 2 µm)	2a (d_{50} = 16.8 µm)	2b (d_{50} = 16.8 µm)	3 (d_{50} = 155 µm)	4 (d_{50} = 760 µm)	5 (d_{50} = 4,025 µm)
Mudflat cells below RM 8.3 for ROD Remedy	35	5.8	0	3	0	3	23.6	18.1	52.3
Channel cells below RM 8.3 for ROD Remedy	36	3.8	0	0.5	0	0.5	37.7	26.6	34.7
RM 10.9 area cells**	37	2,000	0	0	0	0	0	0	100
IR cells**	38	3.8	0	0.25	0	0.25	4.6	42.8	52.1

Notes:
* Based on USEPA FFS model settings, applied to CPG ST model sediment size classes.
** These cap properties are applied only in the subset of simulations that represent capping in the ST model (i.e., the Scenario-specific ST runs and only for cells with a fractional area remediated of 50% or higher; see Table 4).
µm: micrometer
cm: centimeter
CPG: Cooperating Parties Group
FS: feasibility study
ID: identification
IR: Interim Remedy
RM: river mile
ROD: Record of Decision
ST: sediment transport
USEPA: U.S. Environmental Protection Agency

Table 4
Representation of Sediment Bed Adjustments and Dredge Resuspension Release to the Water Column in the ST, OC, and CFT Models During the Upper 9 Miles IR

Projection Number	Simulation of Interim Remedy Sediment Bed Adjustments Due to Dredging/Capping		Simulation of Interim Remedy Mass Release to Water Column Due to Dredging/Capping	
	ST/OC Model (Grain Size and OC Content)	CFT Model (Contaminant Concentration)	ST/OC Model (Sediment and OC Release)	CFT Model (Contaminant Release)
1	No	Yes	No	Yes (3%)
2	No	Yes	No	Yes (3%)
3	No	Yes	No	Yes (3%)
4	No	Yes	No	Yes (3%)
5	No	Yes	No	Yes (3%)
6	Yes	Yes	Yes (3%)	Yes (3%)
7	Yes	Yes	Yes (3%)	Yes (3%)
8	Yes	Yes	Yes (3%)	Yes (3%)
9	Yes	Yes	Yes (3%)	Yes (3%)
10	No	Yes	No	Yes (1%)
11	No	Yes	No	Yes (1%)
12	No	Yes	No	Yes (1%)
13	No	Yes	No	Yes (1%)
14	No	Yes	No	Yes (1%)
15	Yes	Yes	Yes (1%)	Yes (1%)
16	Yes	Yes	Yes (1%)	Yes (1%)
17	Yes	Yes	Yes (1%)	Yes (1%)
18	Yes	Yes	Yes (1%)	Yes (1%)
19	No	Yes	No	Yes (3%)
20	No	Yes	No	Yes (3%)
21	Yes	Yes	Yes (3%)	Yes (3%)
22	Yes	Yes	Yes (3%)	Yes (3%)

Note:
The above table summarizes the settings for the IR in the upper 9 miles only; bed adjustments due to capping and releases of sediment, OC, and contaminant to the water column during dredging are represented during the lower 8 miles ROD remedy in all simulations (including Alternative 1 [NFA; Projections 1 and 10 in Table 1]).
CFT: contaminant fate and transport
IR: Interim Remedy
MNR: monitored natural recovery
OC: organic carbon
ROD: Record of Decision
ST: sediment transport

Table 5
Regression Equations Used to Convert Model-Predicted Tetra-CB to Total PCBs

Model Metrics	Total PCB Concentration	Tetra-CB Concentration Range
Surface Sediment SWAC (mg/kg)	4.01 x Tetra-CB	0 mg/kg ≤ Tetra-CB < 0.05 mg/kg
	4.19 x Tetra-CB - 0.0092	0.05 mg/kg ≤ Tetra-CB < 0.10 mg/kg
	3.19 x Tetra-CB + 0.091	0.10 mg/kg ≤ Tetra-CB < 1.0 mg/kg
	2.91 x Tetra-CB + 0.37	1.0 mg/kg ≤ Tetra-CB
Water Column Concentration (ng/L)	3.34 x Tetra-CB	All concentrations
Water Column Downstream Load (kg/year)	3.34 x Tetra-CB	All concentrations
Gross Erosion Flux (kg/year)	2.99 x Tetra-CB	All concentrations
Net Erosion Flux (kg/year)	2.99 x Tetra-CB	All concentrations
Concentration on Depositing Fine Sediment (mg/kg)	3.34 x Tetra-CB	All concentrations

Notes:
kg/year: kilograms per year
mg/kg: milligrams per kilogram
ng/L: nanogram per liter
PCB: polychlorinated biphenyl
SWAC: surface area-weighted average concentration
tetra-CB: tetrachlorobiphenyl

Table 6
Summary of Irregularities Noted in FS Projection Simulations

No.	Irregularity	Cause of Irregularity	Impacted Runs	Impact to FS Metrics
1	An HD/ST rerun of Year 6 was adopted in the CFT run to correct a spike of water column COC concentration during Day 42 of Year 6, but the remaining years of the HD/ST run were not updated	An HD/ST model fix was implemented for year 6 only, to correct a small negative salinity prediction which caused a spurious CFT model partitioning prediction and the resulting concentration spike	Alternative 2 using Scenario-specific ST and 1% dredge resuspension for 2,3,7,8-TCDD and tetra-CB (Projection 15 in Table 1)	A rerun of the full CFT run with the updated HD/ST result for Year 6 removed the COC concentration spike; a rerun with updated HD/ST for remaining years is unlikely to have material impact to Section 8 figures and comparison of model metric ranges
2	Minor discontinuities in bed thicknesses at the beginning of the IR in Year 4 (Day 274)	The Scenario-specific ST runs with 1% dredge resuspension runs were inadvertently restarted in Year 4 from the 3% ST run	Alternatives 2, 3, 4, and 5 using Scenario-specific ST and 1% dredge resuspension for 2,3,7,8-TCDD and tetra-CB (Projections 15 through 18 in Table 1)	Small deviation from the corresponding run with MNR ST was noted in surface sediment SWAC in RM 0 to RM 8.3. Likely no discernible impact to Section 8 figures and comparison of model metric ranges, given the issue affects all active alternatives equally and occurs before the IR.
3	Inconsistent bed thickness in select cells prior to the beginning of IR in Year 4 (Day 274)	The issue appears related to the Year 4 OC coupling (cause unknown).	Alternatives 2 and 3 using Scenario-specific ST and 1% dredge resuspension for 2,3,7,8-TCDD and tetra-CB (Projections 15 and 16 in Table 1)	Small deviation from the corresponding run with MNR ST was noted in surface sediment SWAC in RM 0 to RM 8.3. Likely no discernible impact to Section 8 figures and associated ranges of model metrics, given the impact is visible only in a small subset of cells located in the lower LPR.
4	Minor, temporary dip in RM 8.3 to RM 15 SWAC in Year 15 (Days 266 to 280)	Driven by a spike of bulk density in the ST model (cause unknown)	Alternative 5 using Scenario-specific ST and 1% dredge resuspension for 2,3,7,8-TCDD and tetra-CB (Projection 18 in Table 1)	The dip is visible in Appendix C but not Section 8 SWAC figures.
5	Total PCBs SWAC in RM 0 to RM 8.3 is slightly higher in Alternative 3 than Alternative 2 for the Scenario-specific ST with 3% dredge resuspension	Unknown	Alternative 3 using Scenario-specific ST and 3% dredge resuspension for tetra-CB only (Projection 7 in Table 1)	Visible in Section 8 and Appendix C SWAC figures, but the difference has no material impact on the comparison of alternatives in Section 8 of the main FS report.

No.	Irregularity	Cause of Irregularity	Impacted Runs	Impact to FS Metrics
6	Small inconsistency in bed initial condition for tetra-CB	Mapping dry weight IC converted to volumetric model IC using initial bulk densities from MNR ST run instead of Scenario-specific ST run, which differ slightly due to the capping of three cells in the RM 10.9 removal area	Alternatives 2, 3, 4, and 5 using Scenario-specific ST and 1% dredge resuspension for tetra-CB (Projections 15 through 18 in Table 1)	Tetra-CB initial SWAC deviates by 0.9% for RM 8.3 to RM 15 and 0.2% for RM 0 to RM 15. No discernible impact to Section 8 or Appendix C figures.
7	Elevated water column concentrations in Year 17	Driven by spurious cohesive sediment erosion velocities (cause unknown)	Alternative 4 using Scenario-specific ST and 1% dredge resuspension for 2,3,7,8-TCDD and tetra-CB (Projection 17 in Table 1)	Elevated annual mean concentration for Year 17 is visible in Section 8 and in Appendix C figures for portions of this year. A test run substituting Years 17 and 18 with output from the corresponding 3% dredge resuspension ST run removes the water column spikes and demonstrates that Alternative 4 ranges of 10-year average water column concentration and load, gross erosion flux, and depositing fine sediment concentrations of 2,3,7,8-TCDD are minimally affected by removing the observed spike. Thus, the issue is unlikely to impact the comparison of alternatives based on these ranges.

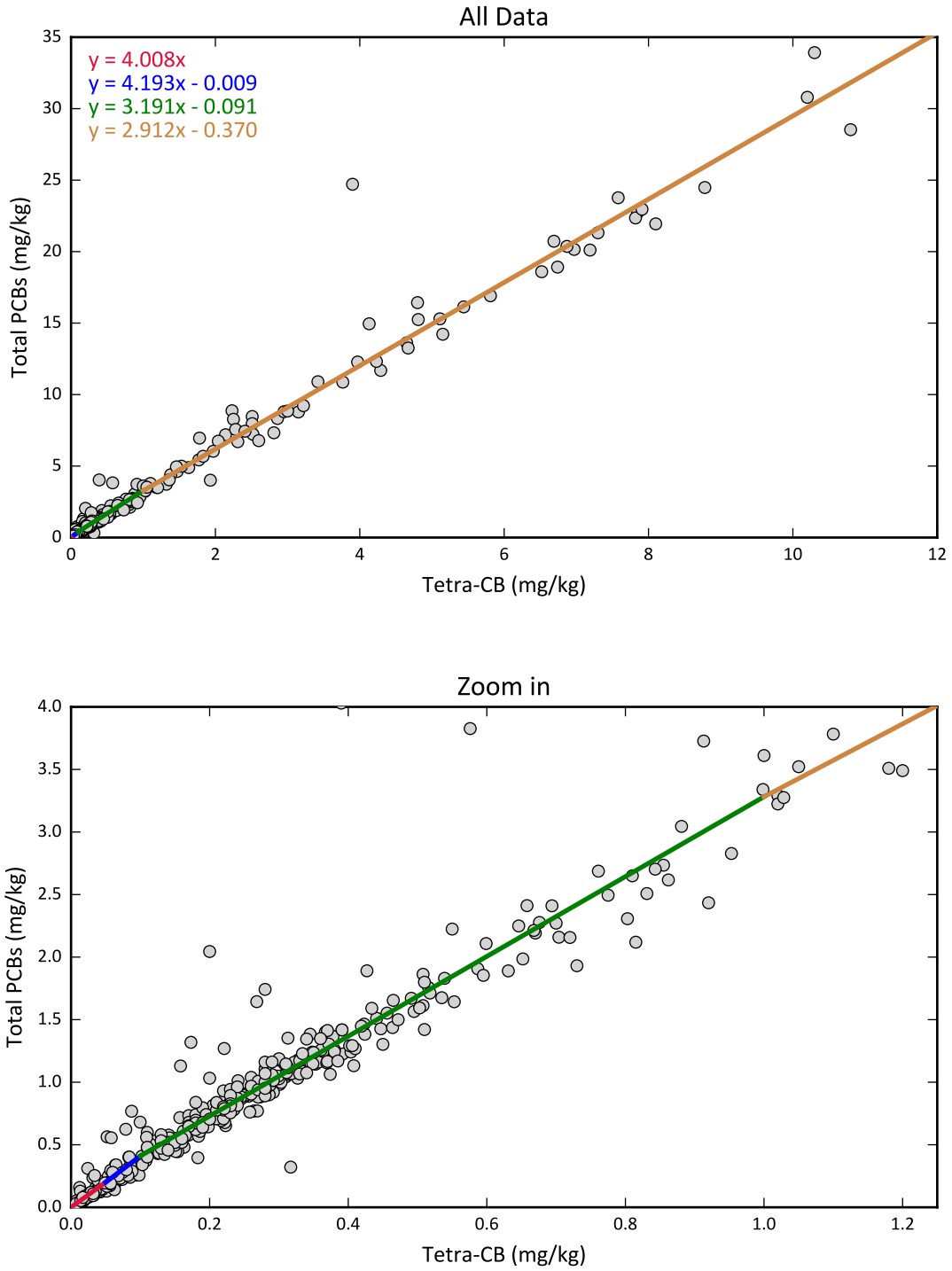
Notes:
2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin
CFT: contaminant fate and transport
COC: chemical of concern
FS: feasibility study
HD: hydrodynamic
IC: initial condition
IR: Interim Remedy
MNR: monitored natural recovery
OC: organic carbon
PCB: polychlorinated biphenyl
RM: river mile
ST: sediment transport
SWAC: surface area-weighted average concentration
tetra-CB: tetrachlorobiphenyl
WY: water year

Table 7
Estimated Surface Sediment SWAC Recovery Half-Lives Over the Post-IR Period

COCs	Alternatives	Projections (by Modeling Approach)			
		MNR ST and 3% Dredge Resuspension[1]	Scenario-Specific ST and 3% Dredge Resuspension[2]	MNR ST and 1% Dredge Resuspension[3]	Scenario-Specific ST and 1% Dredge Resuspension[4]
2,3,7,8-TCDD	1	125	N/A	244	N/A
	2	9.0	8.1	18	16
	3	7.7	7.6	15	13
	4	7.1	7.9	13	13
	5	15	21	36	65
Total PCBs	1	79	N/A	110	N/A
	2	20	18	46	38
	3	18	17	43	33
	4	18	18	43	38
	5	36	44	71	66

Notes:
1. Projections 1 through 5 in Table 1
2. Projections 6 through 9 in Table 1
3. Projections 10 through 14 in Table 1
4. Projections 15 through 18 in Table 1
2,3,7,8-TCDD: 2,3,7,8-tetrachlorodibenzo-p-dioxin
COC: chemical of concern
IR: Interim Remedy
MNR: monitored natural recovery
N/A: Not applicable
PCB: polychlorinated biphenyl
ST: sediment transport
SWAC: surface area-weighted average concentration

Figures



Notes:
Straight line represents linear regression. Non-detect samples removed. Surface sediments include top 6 inches of sediment.
Data sources: Sediment data collected during 2005 to 2013 in river miles 0 to 17.
Sediment outliers 12A-0421, 13B-0542, and CLRC-035 were removed.

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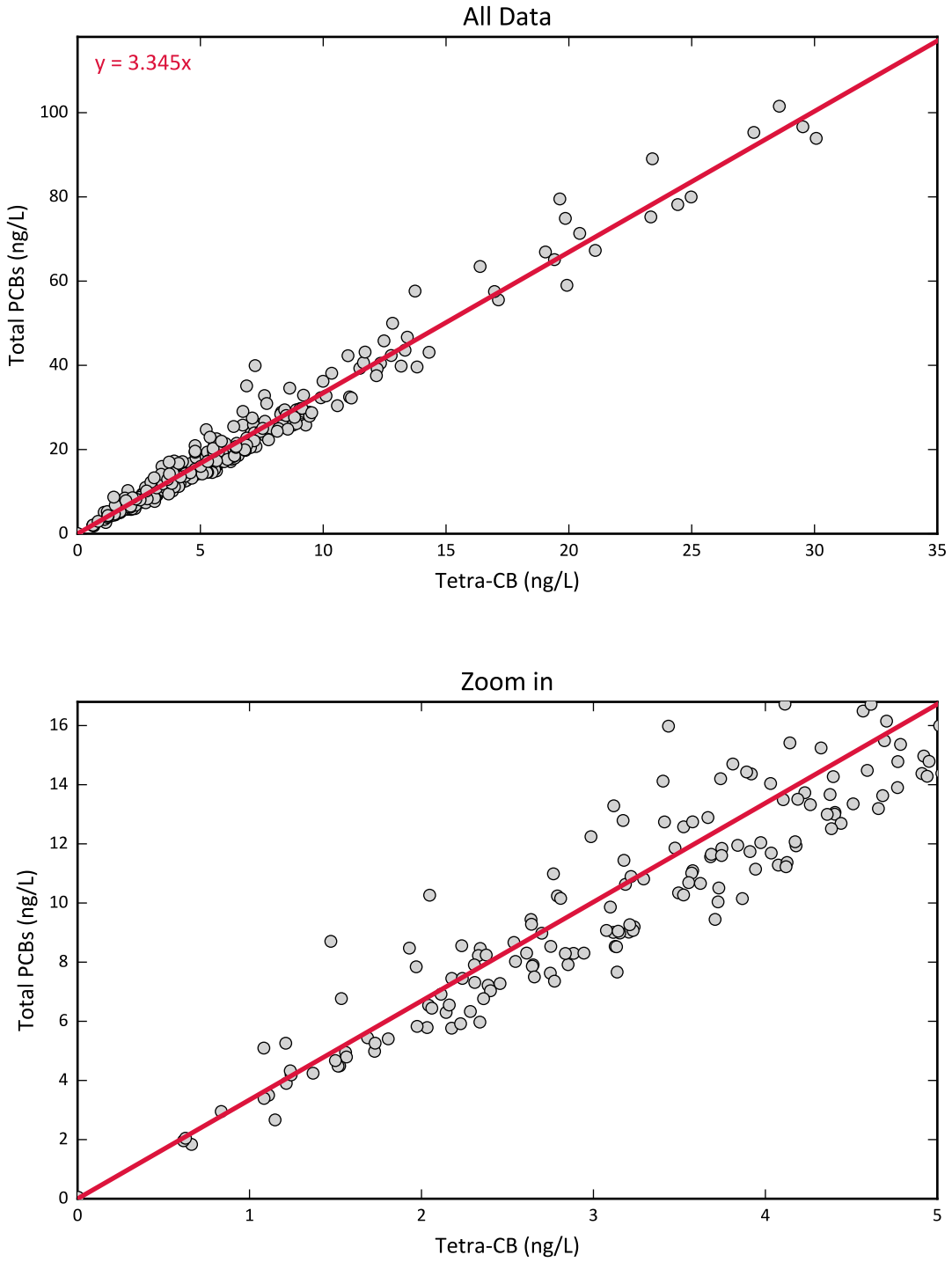
File Path: \\IRIS\Woodcliff\Projects\Passaic_CPG\ANALYSIS\RIFS_draft2\python\sed_wc_combined_correlation_plotter_customreg_1panel.py

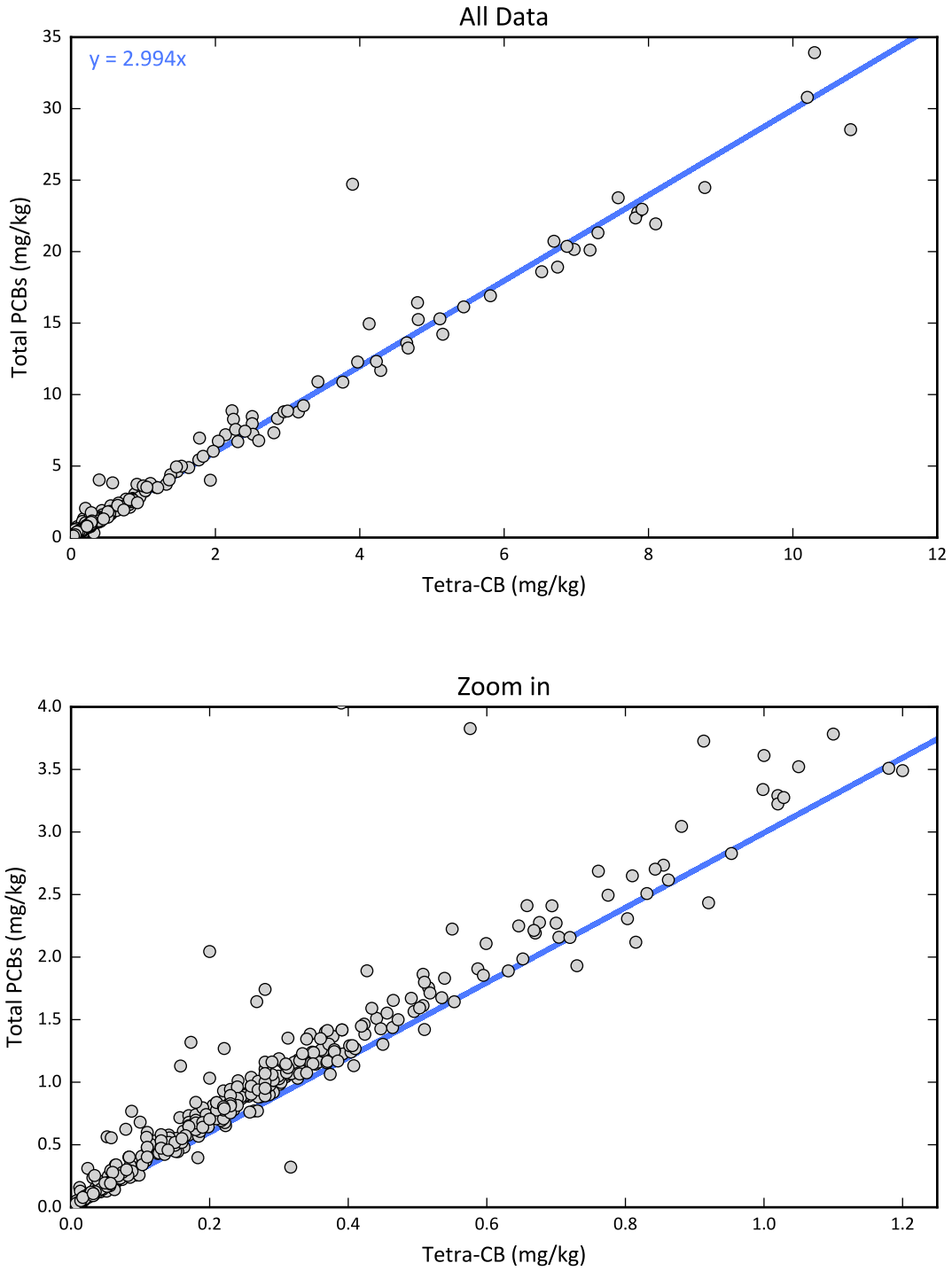
Figure 1
Regression of Tetra-CB to Total PCBs for Sediment SWAC
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Straight line represents linear regression. Non-detect samples removed.
Water column data collected from sv-CWCM during 2011 to 2013 in river miles 0 to 17.
Water outlier 12G-CE02-T102-B was removed.

Publish Date: 08/06/2020 15:46 PM | User: WCL-ATLAS
File Path: \\IRIS\Woodcliff\Projects\Passaic_CPG\ANALYSIS\RIFS_draft2\python\sed_wc_combined_correlation_plotter_customreg_1panel.py

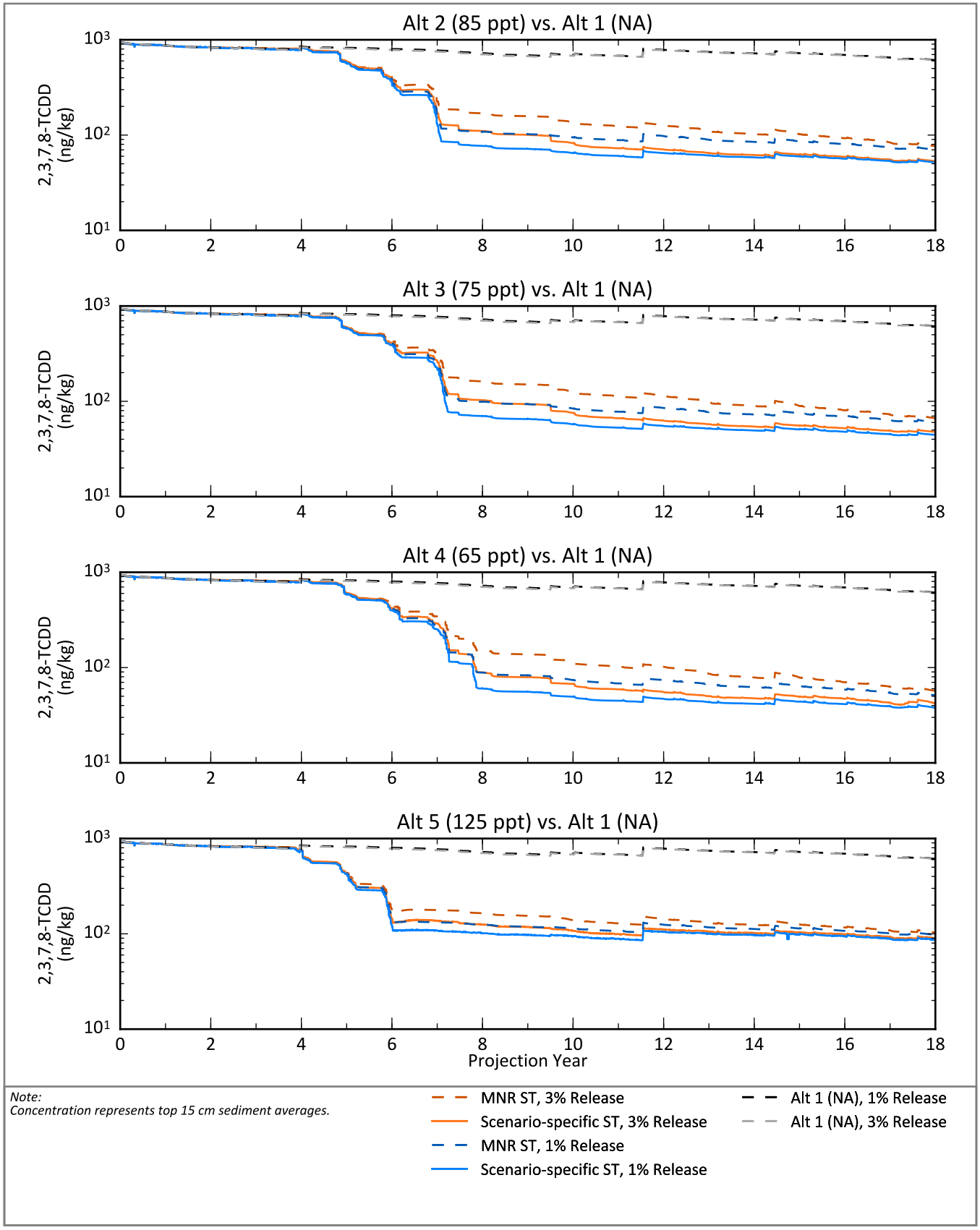
Figure 2
Regression of Tetra-CB to Total PCBs for
Water Column Concentration, Downstream Load, and Concentration on Depositing Fine Sediments
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Straight line represents linear regression. Non-detect samples removed. Surface sediments include top 6 inches of sediment.
Data sources: Sediment data collected during 2005 to 2013 in river miles 0 to 17.
Sediment outliers 12A-0421, 13B-0542, and CLRC-035 were removed.

Publish Date: 08/06/2020 15:48 PM | User: WCL-ATLAS
File Path: \\IRIS\Woodcliff\Projects\Passaic_CPG\ANALYSIS\RIFS_draft2\python\sed_wc_combined_correlation_plotter_customreg_1panel.py

Figure 3
Regression of Tetra-CB to Total PCBs for Gross and Net Erosion Flux
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



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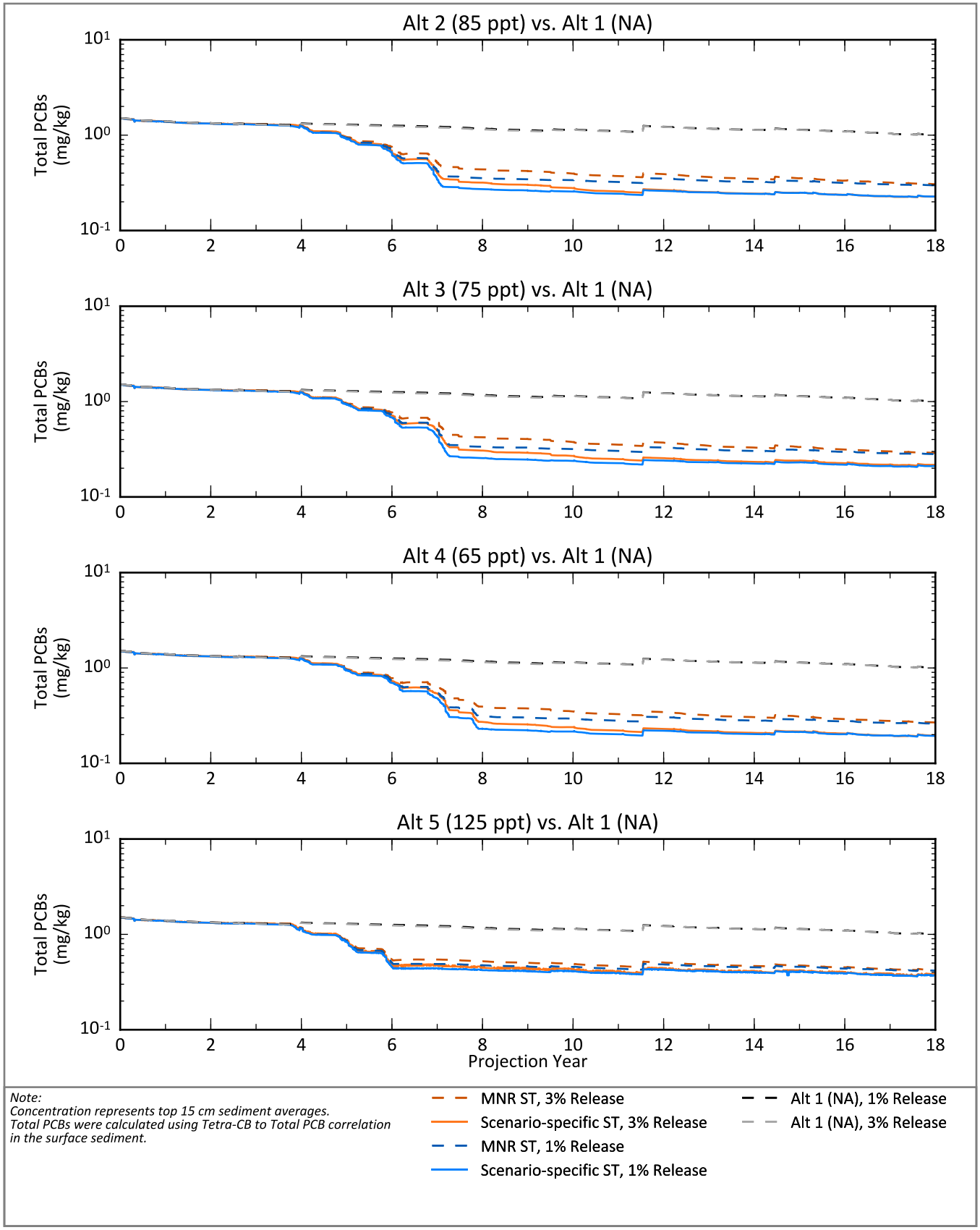
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 4a

Projected Surface Sediment SWAC in RM 8.3 to 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



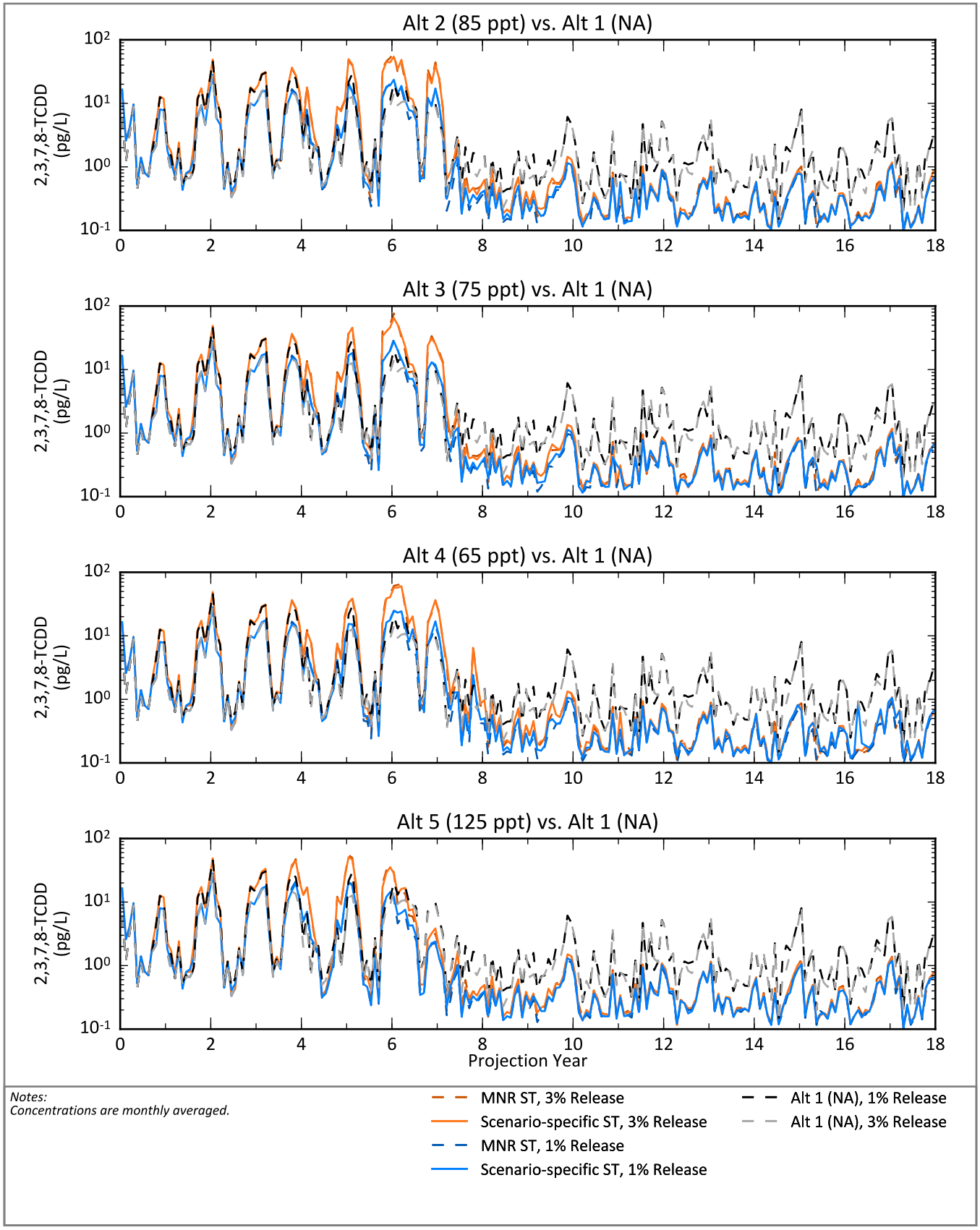
Publish Date: 08/06/2020 15:25 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 4b

Projected Surface Sediment SWAC in RM 8.3 to 15 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



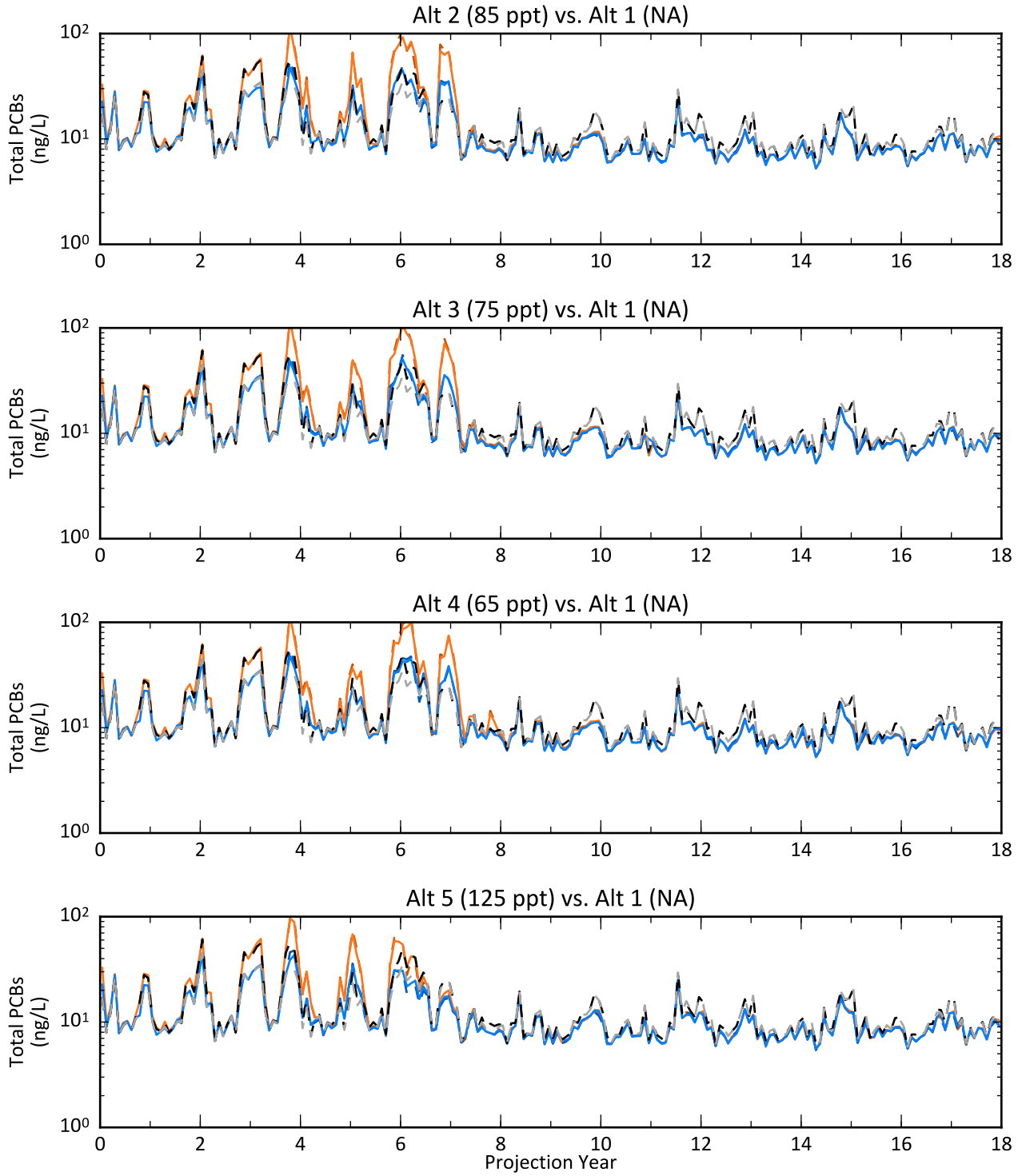
Publish Date: 08/06/2020 15:25 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 5a

Projected Water Column Concentration in RM 8.3 to 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Concentrations are monthly averaged.
Total PCBs were calculated using Tetra-CB to Total PCB correlation in the water column.

- MNR ST, 3% Release
- Scenario-specific ST, 3% Release
- MNR ST, 1% Release
- Scenario-specific ST, 1% Release
- Alt 1 (NA), 1% Release
- Alt 1 (NA), 3% Release

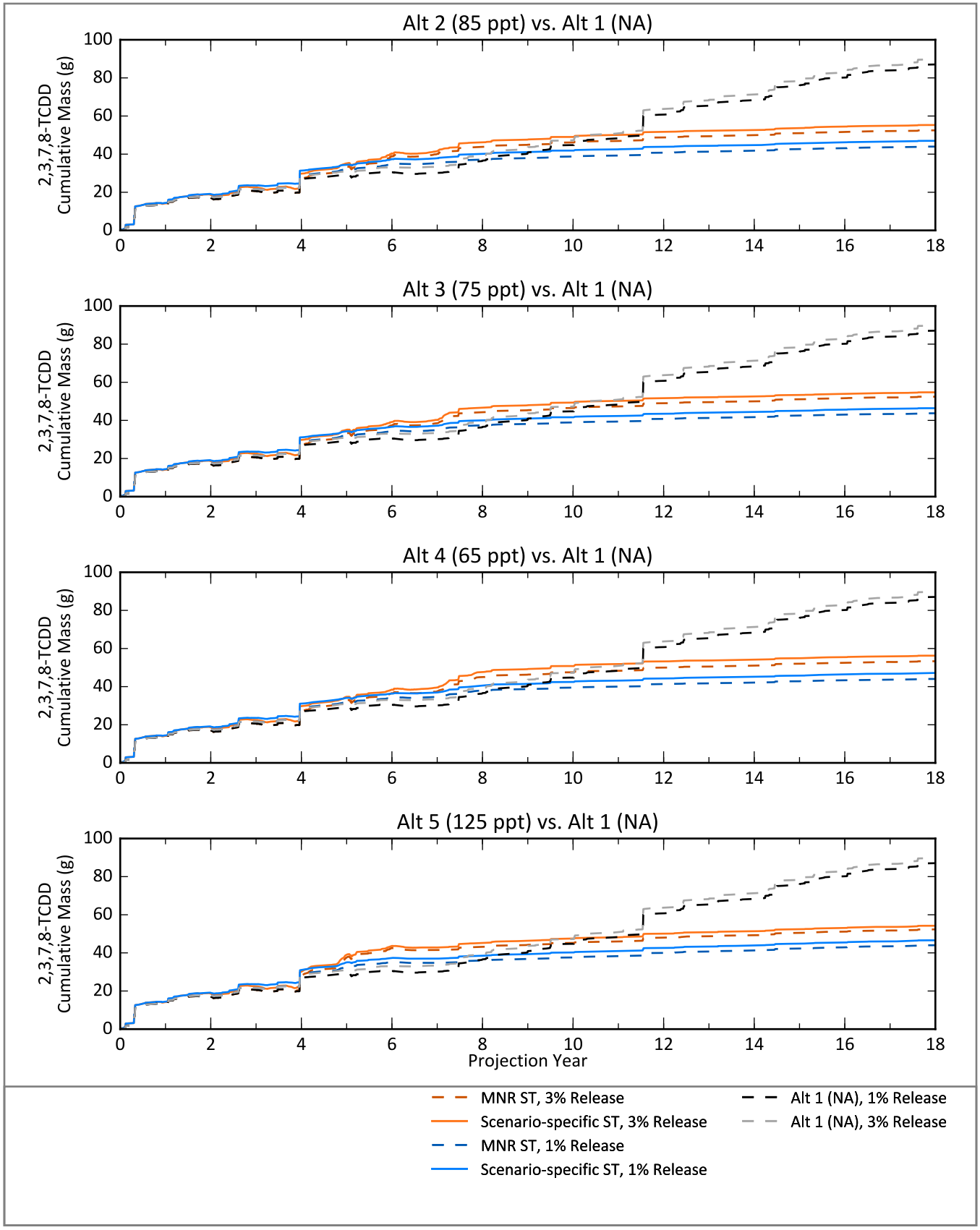
Publish Date: 08/06/2020 15:25 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 5b

Projected Water Column Concentration in RM 8.3 to 15 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



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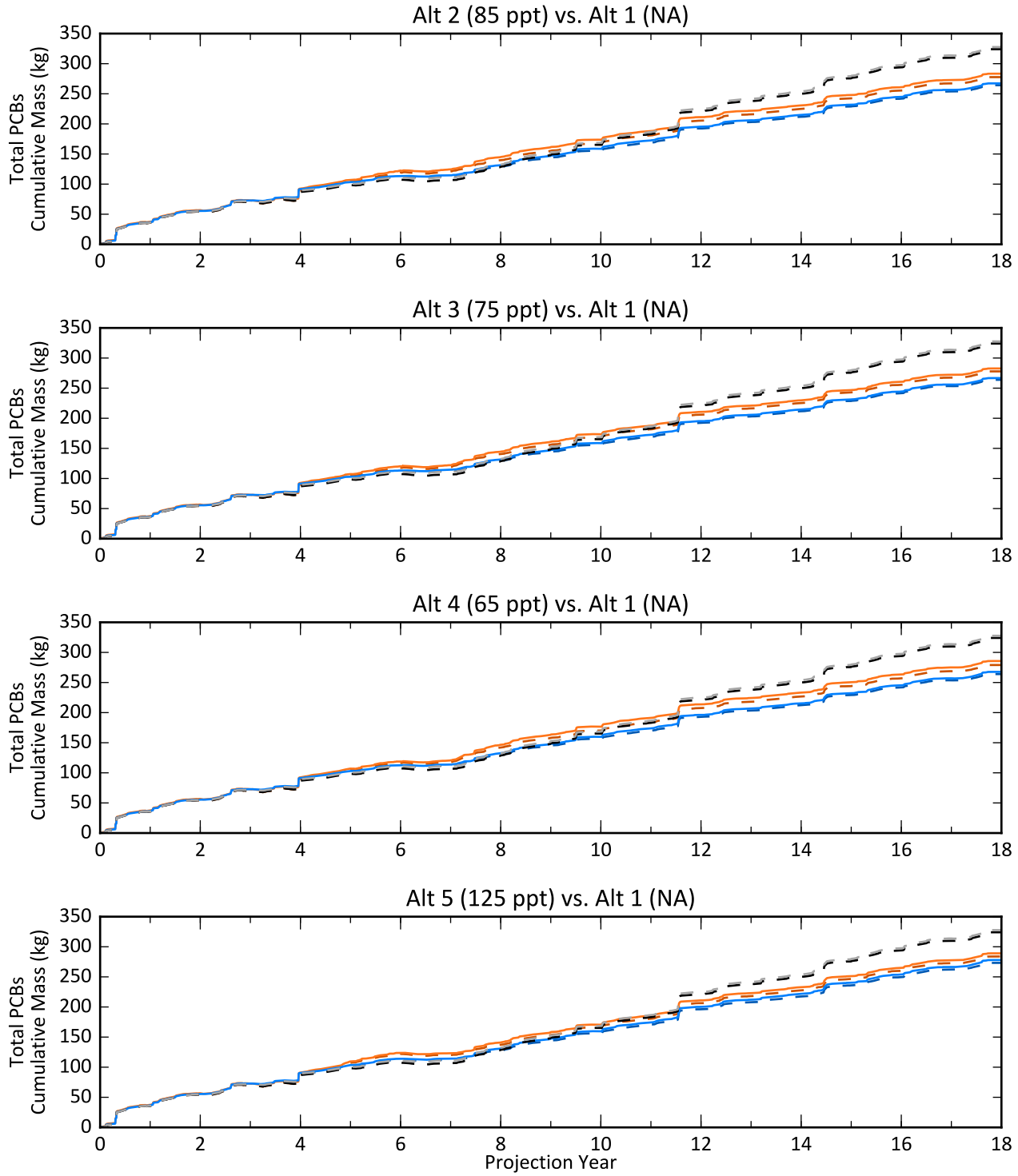
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 6a

Projected Cumulative Water Column Downstream Load at RM 8.3 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Total PCBs were calculated using Tetra-CB to Total PCB correlation from the water column net downstream load.

- MNR ST, 3% Release
- Scenario-specific ST, 3% Release
- MNR ST, 1% Release
- Scenario-specific ST, 1% Release
- Alt 1 (NA), 1% Release
- Alt 1 (NA), 3% Release

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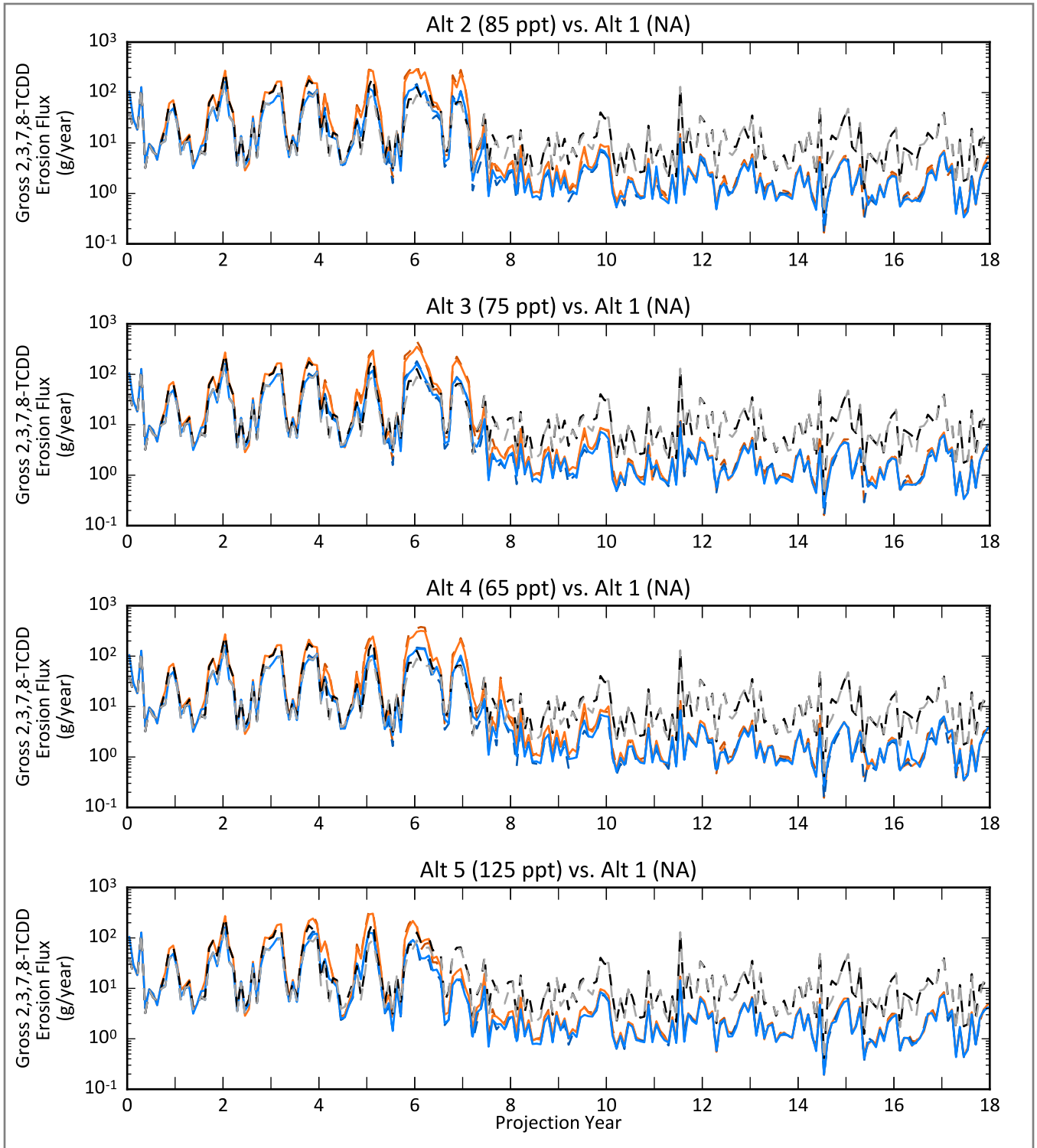
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 6b

Projected Cumulative Water Column Downstream Load at RM 8.3 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Gross erosion fluxes are monthly averaged.

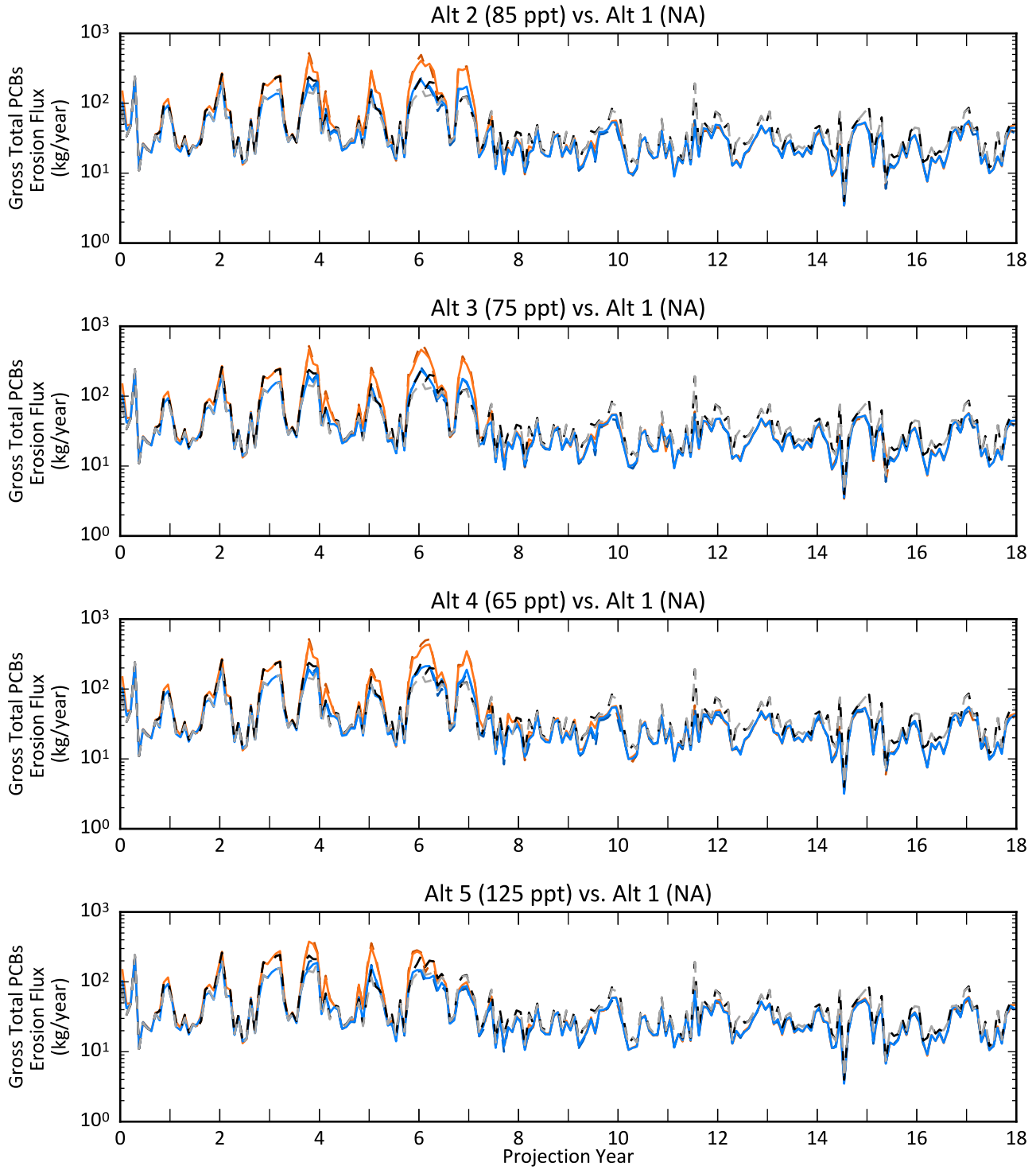
Publish Date: 08/06/2020 15:25 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 7a

Projected Gross Erosion Flux in RM 8.3 to RM 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

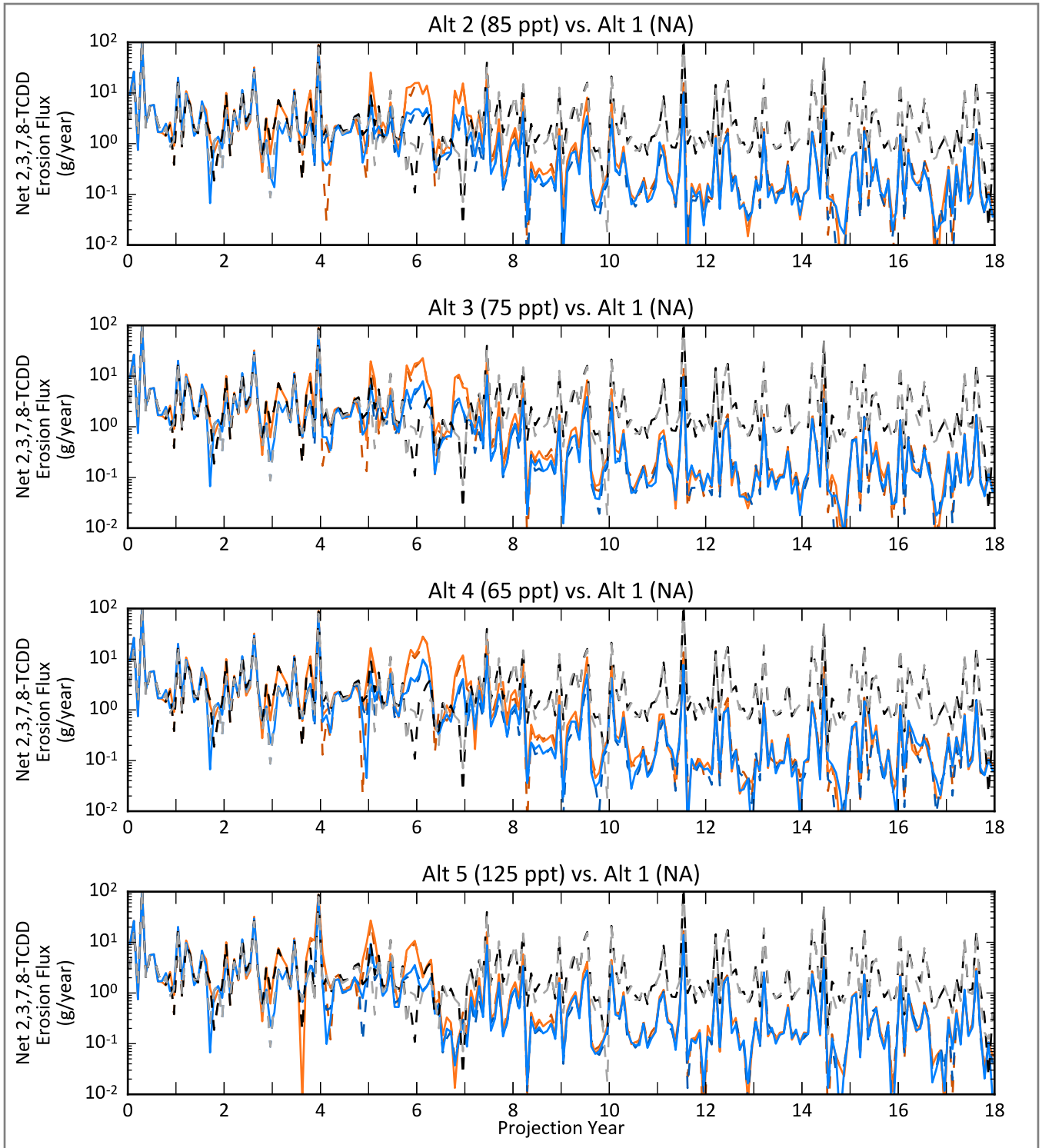
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Gross erosion fluxes are monthly averaged.
Total PCBs were calculated using Tetra-CB to Total PCB correlation for the erosion fluxes.

Publish Date: 08/06/2020 15:25 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 7b
Projected Gross Erosion Flux in RM 8.3 to RM 15 for Total PCBs
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



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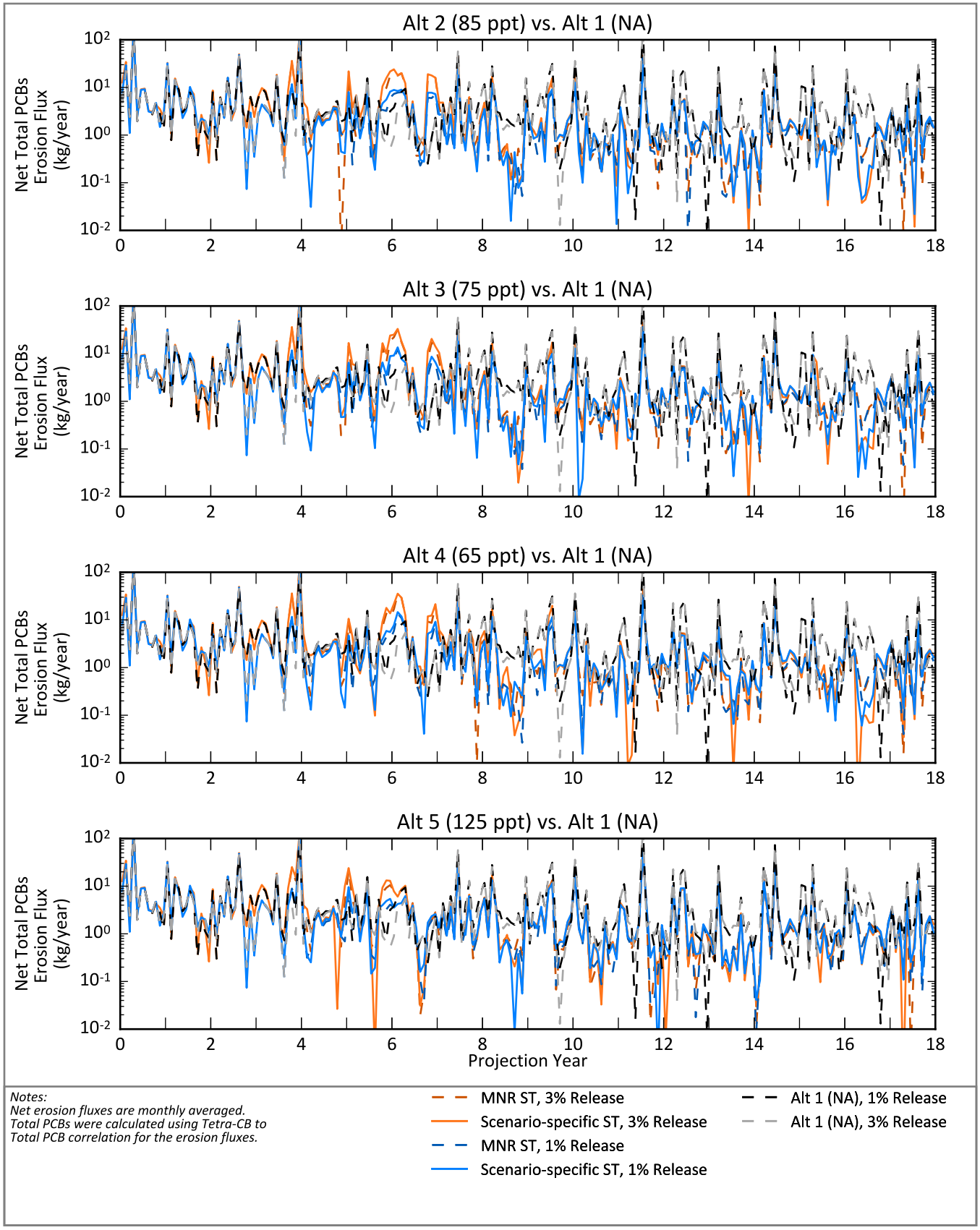
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 8a

Projected Net Erosion Flux in RM 8.3 to RM 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



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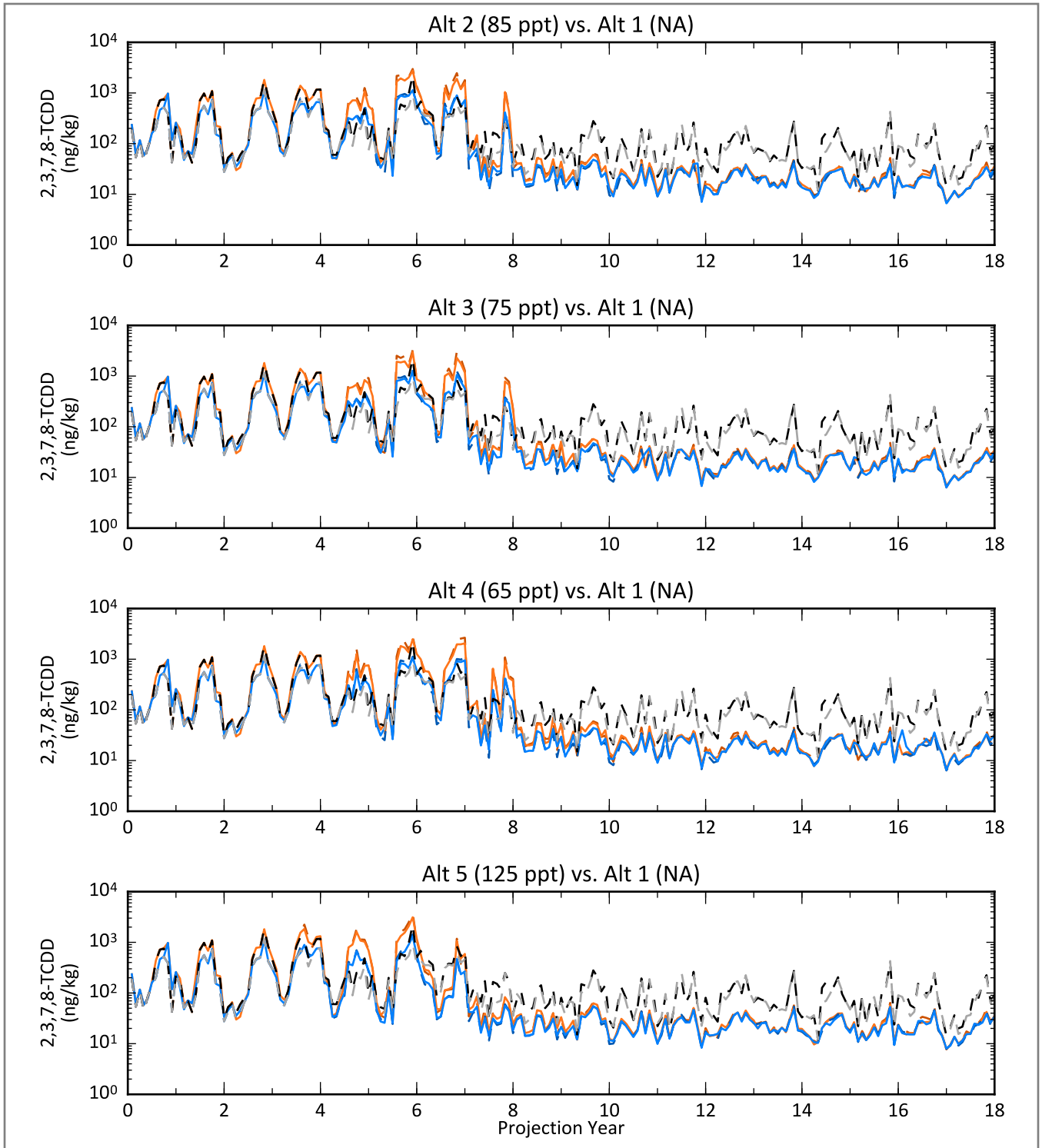
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 8b

Projected Net Erosion Flux in RM 8.3 to RM 15 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Concentrations were computed as the ratio of monthly deposition fluxes in RM 8.3 to RM 15 between contaminate and cohesive solids.

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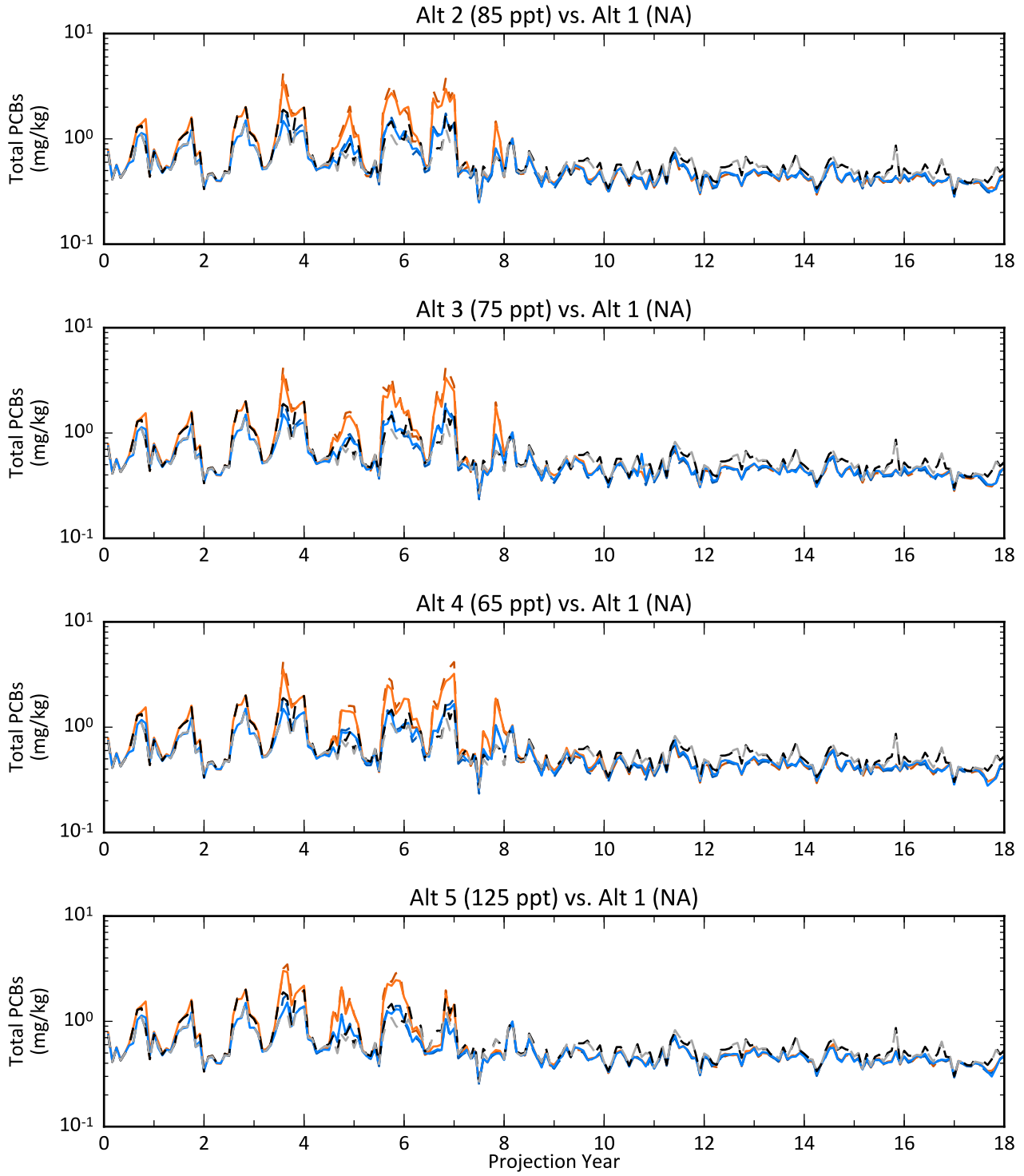
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 9a

Projected Concentration on Depositing Fine Sediments in RM 8.3 to RM 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Concentrations were computed as the ratio of monthly deposition fluxes in RM 8.3 to RM 15 between contaminate and cohesive solids.
Total PCBs were calculated using Tetra-CB to Total PCB correlation in the depositing fine sediments.

- MNR ST, 3% Release
- Scenario-specific ST, 3% Release
- MNR ST, 1% Release
- Scenario-specific ST, 1% Release
- Alt 1 (NA), 1% Release
- Alt 1 (NA), 3% Release

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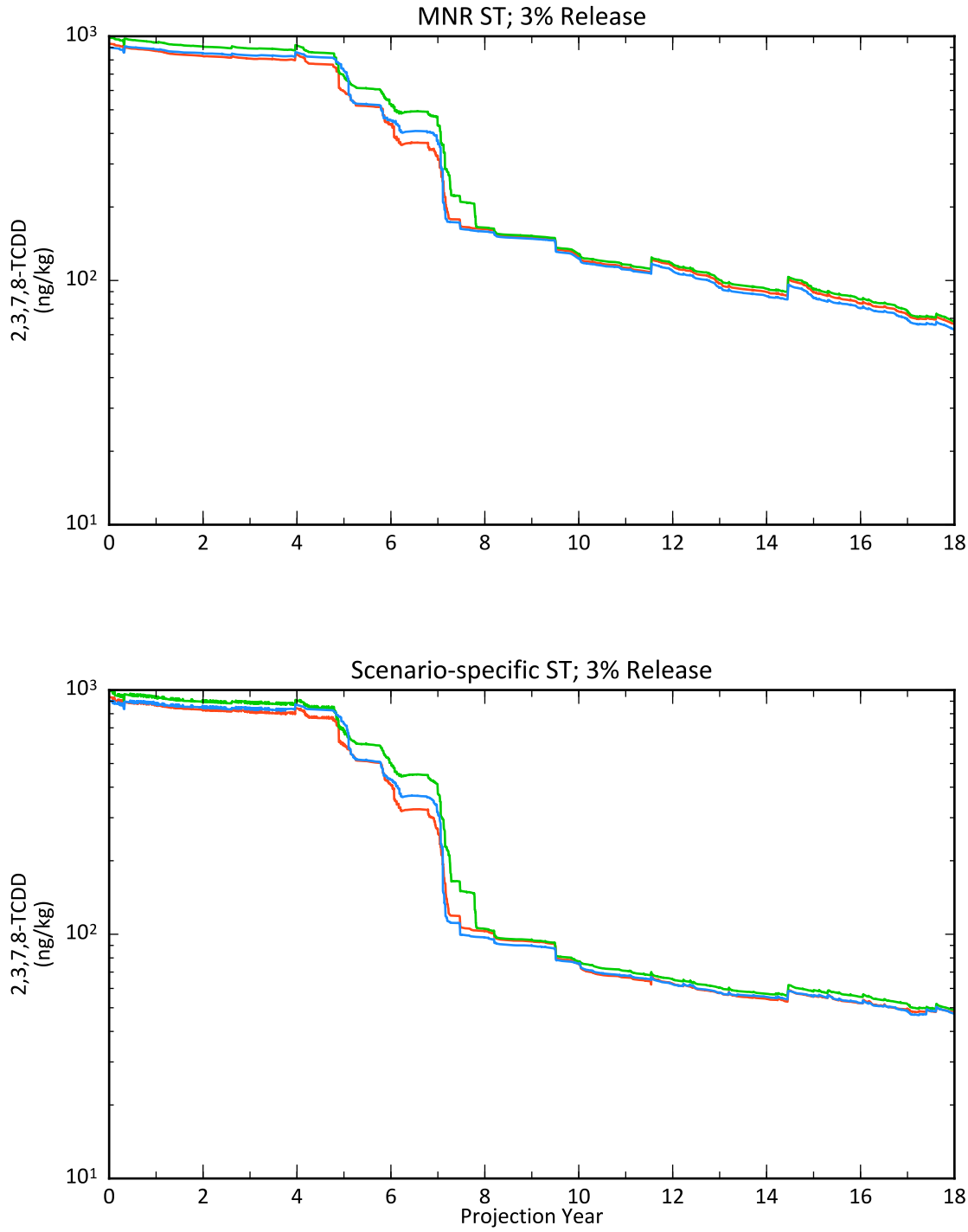
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 9b

Projected Concentration on Depositing Fine Sediments in RM 8.3 to RM 15 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note:
Concentration represents top 15 cm sediment averages.

CS 37
CS 57
CS 81

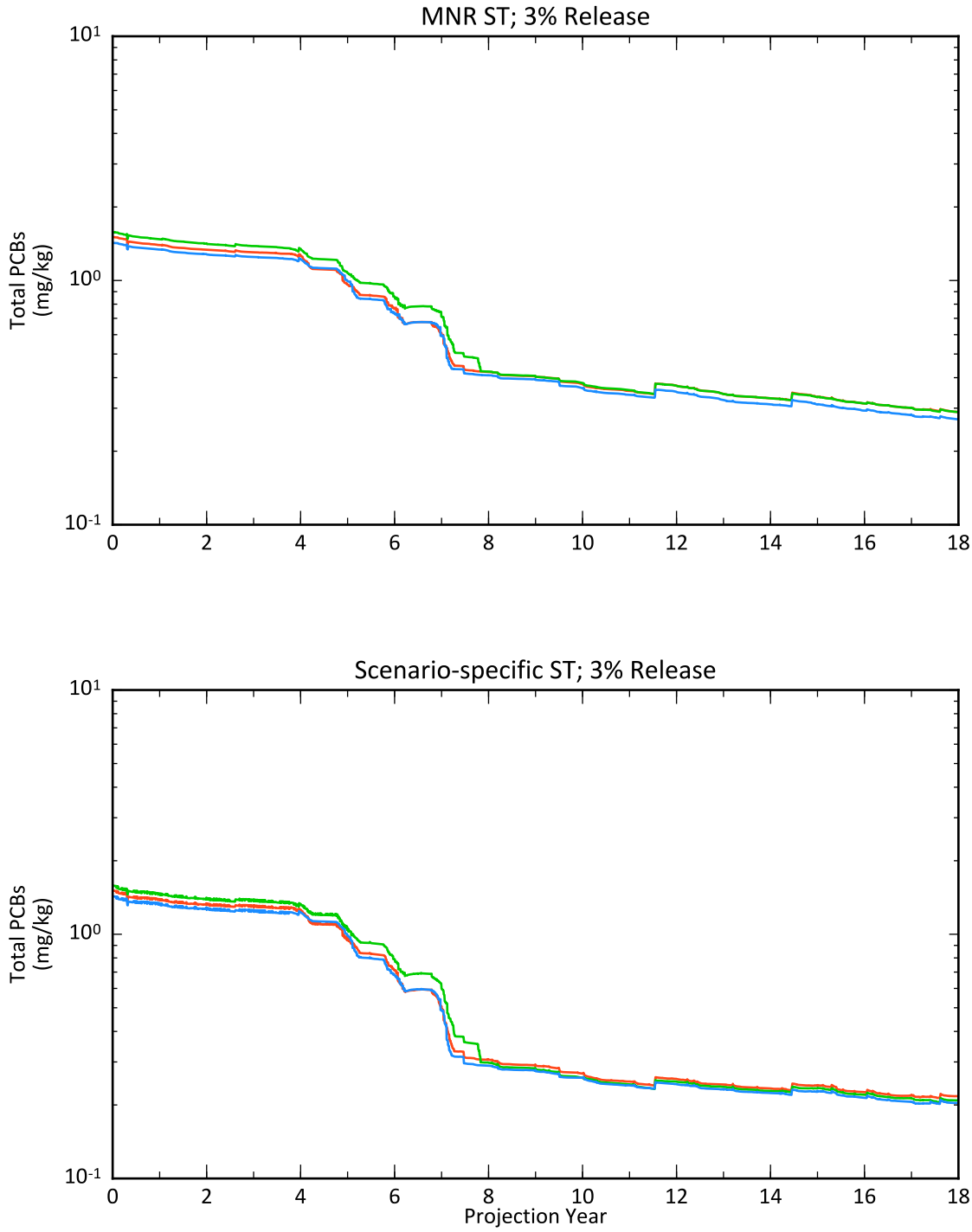
Publish Date: 08/06/2020 15:27 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 10a

Mapping Uncertainty Results for Alternative 3: Surface Sediment SWAC in RM 8.3 to RM 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note:
Concentration represents top 15 cm sediment averages.
Total PCBs were calculated using Tetra-CB to Total PCB correlation in the surface sediment.

CS 37
CS 57
CS 81

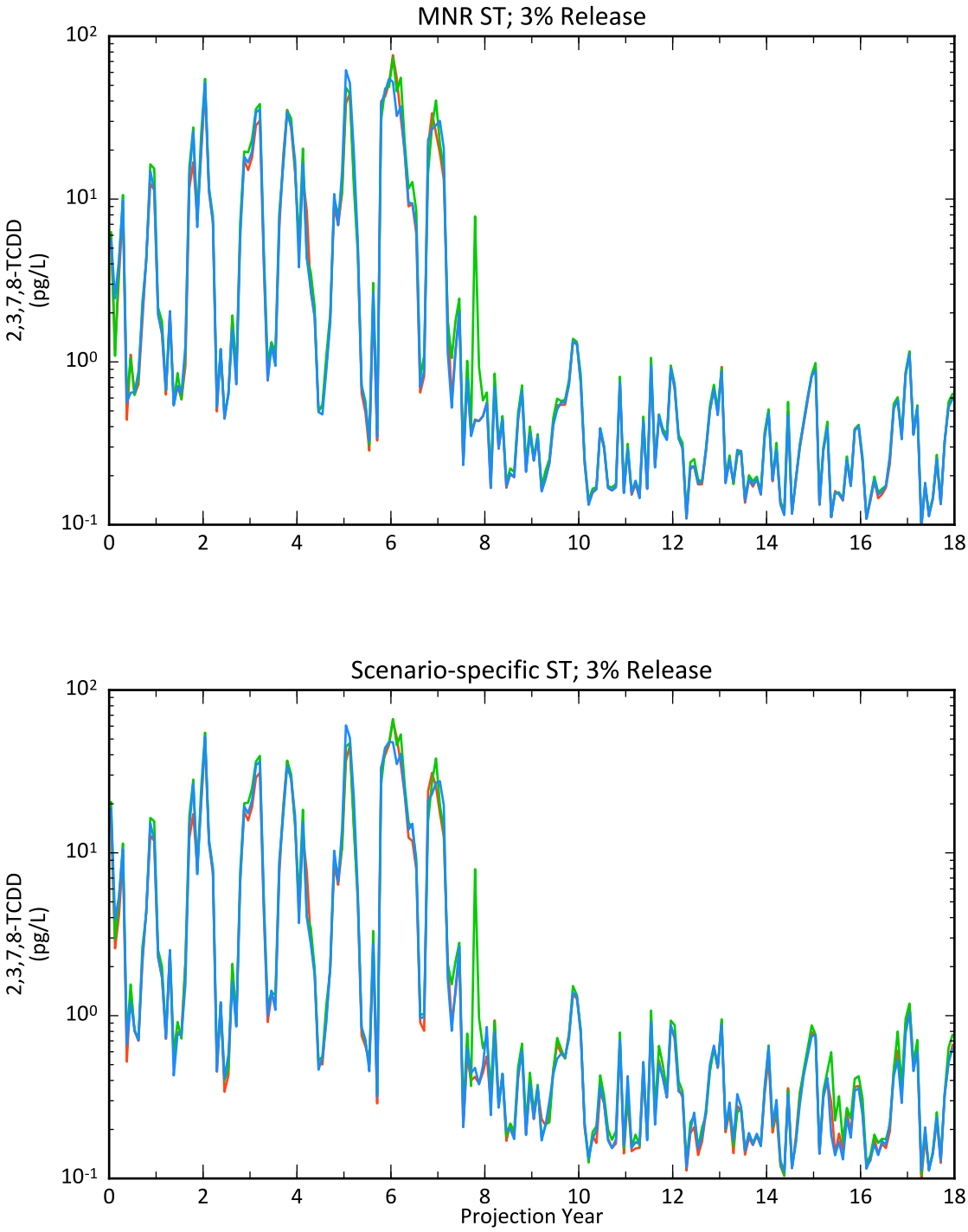
Publish Date: 08/06/2020 15:27 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 10b

Mapping Uncertainty Results for Alternative 3: Surface Sediment SWAC in RM 8.3 to RM 15 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Concentrations are monthly averaged.

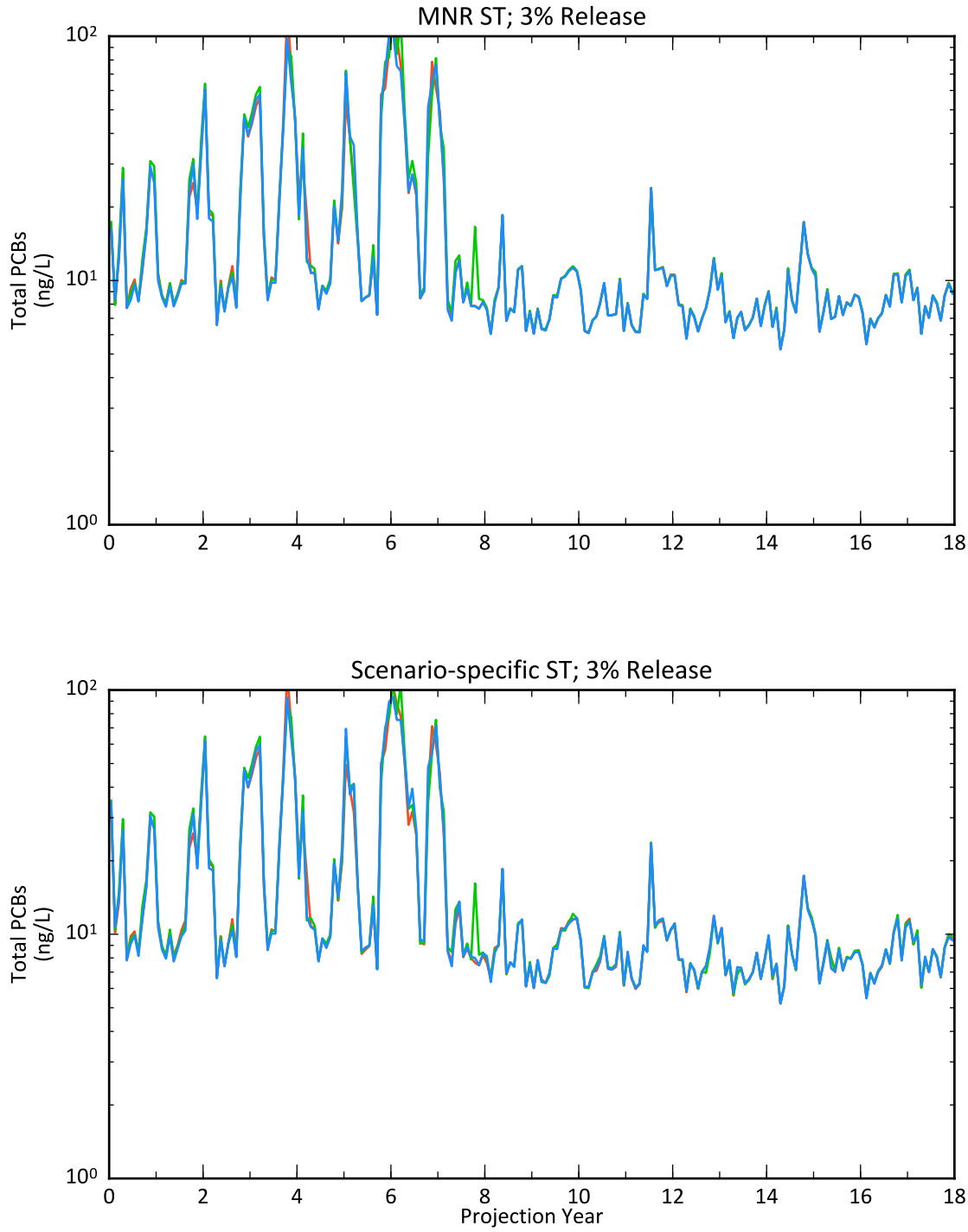
Publish Date: 08/06/2020 15:27 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 11a

Mapping Uncertainty Results for Alternative 3: Water Column Concentration in RM 8.3 to RM 15 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Concentrations are monthly averaged.
Total PCBs were calculated using Tetra-CB to Total PCB correlation in the water column.

CS 37
CS 57
CS 81

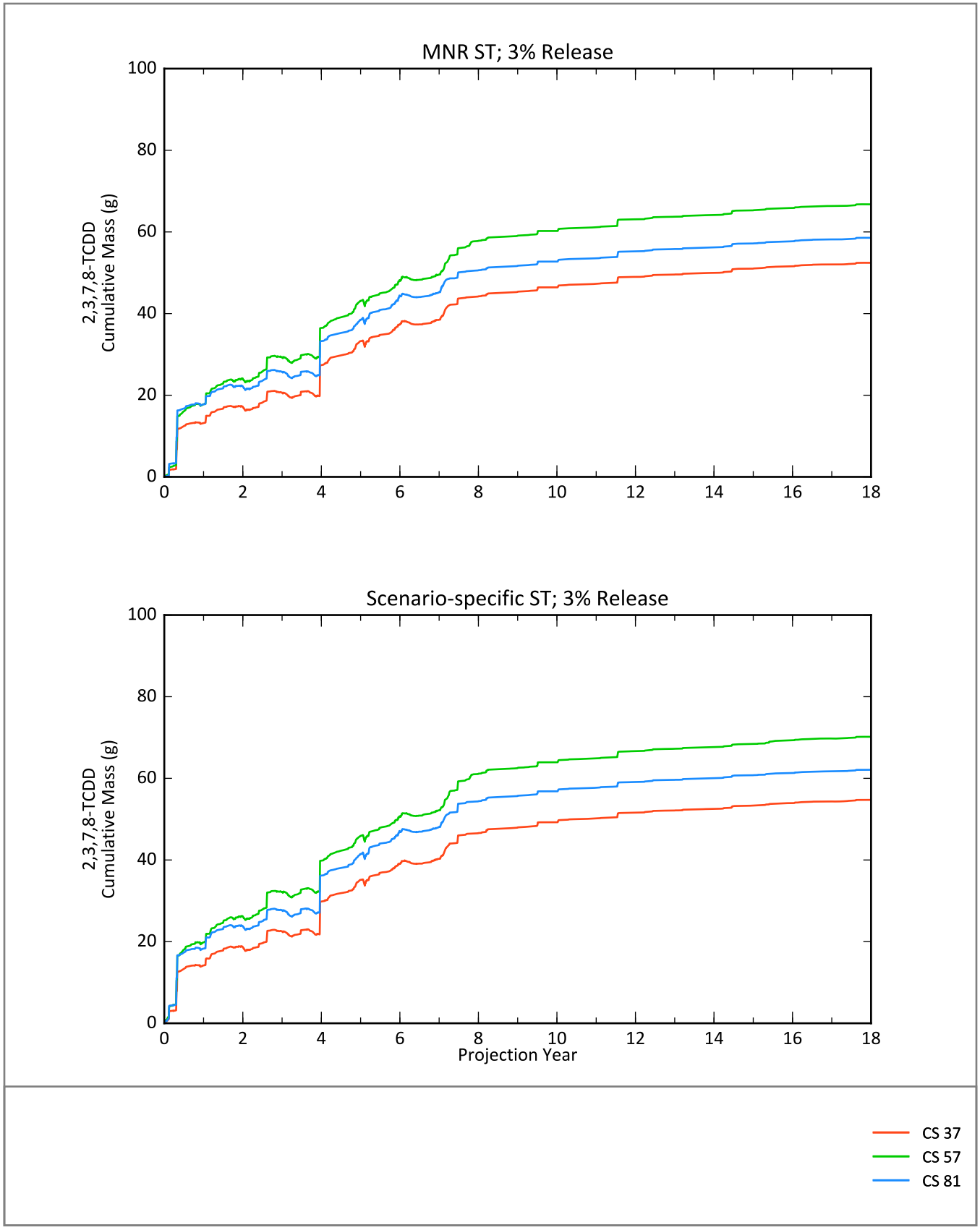
Publish Date: 08/06/2020 15:27 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 11b

Mapping Uncertainty Results for Alternative 3: Water Column Concentration in RM 8.3 to RM 15 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



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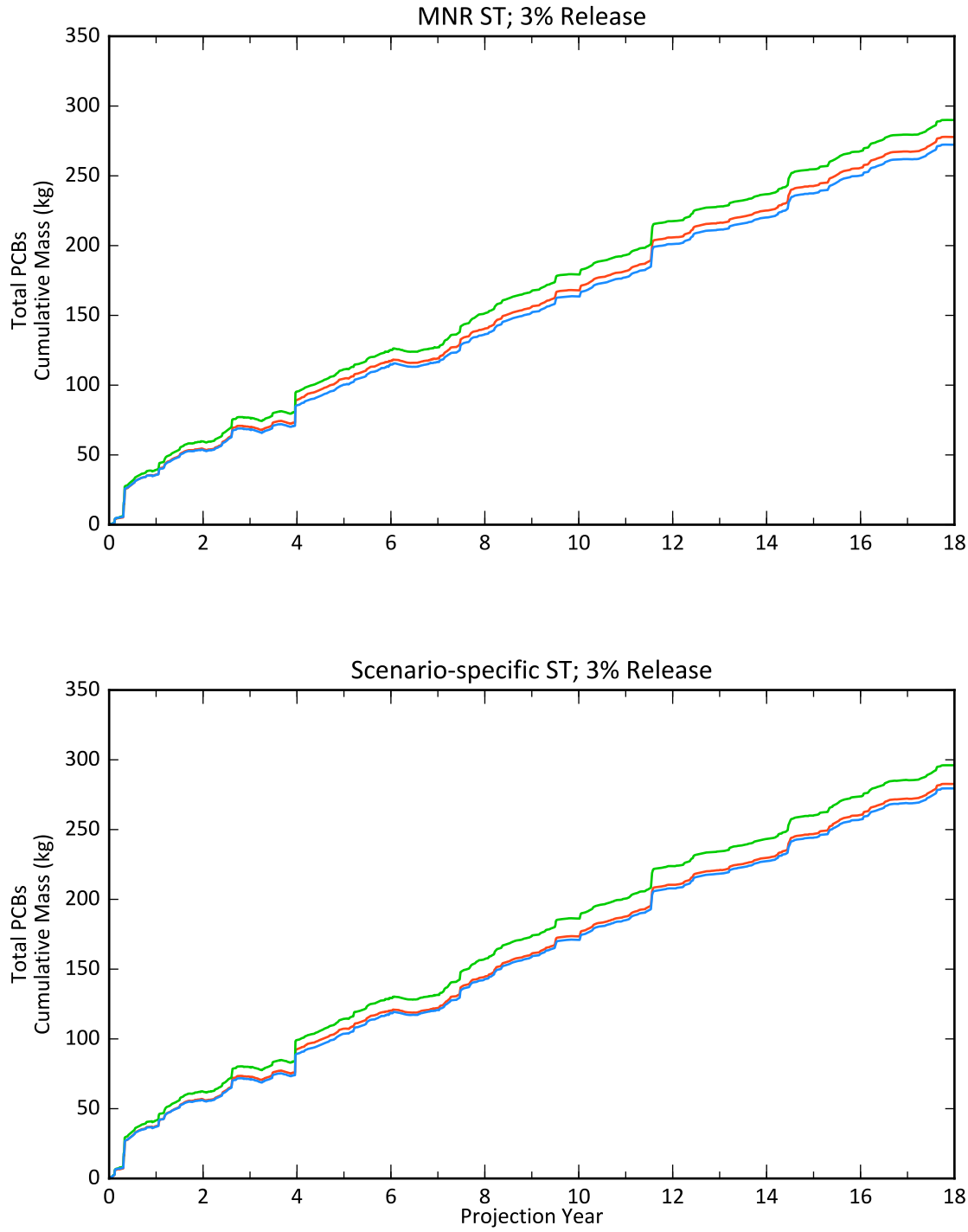
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

Figure 12a

Mapping Uncertainty Results for Alternative 3: Cumulative Water Column Downstream Load at RM 8.3 for 2,3,7,8-TCDD

Upper 9-Mile Source Control Interim Remedy Feasibility Study

Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Notes:
Total PCBs were calculated using Tetra-CB to Total PCB correlation from the water column net downstream load.

Publish Date: 08/06/2020 15:27 PM | User: WCL-ATLAS
File Path: \\TYCHE\CPGpas2\MODEL\CFM\python\projections\plotting\FS_Appendic_C_Apr_2020_Plotting_Funcs.py

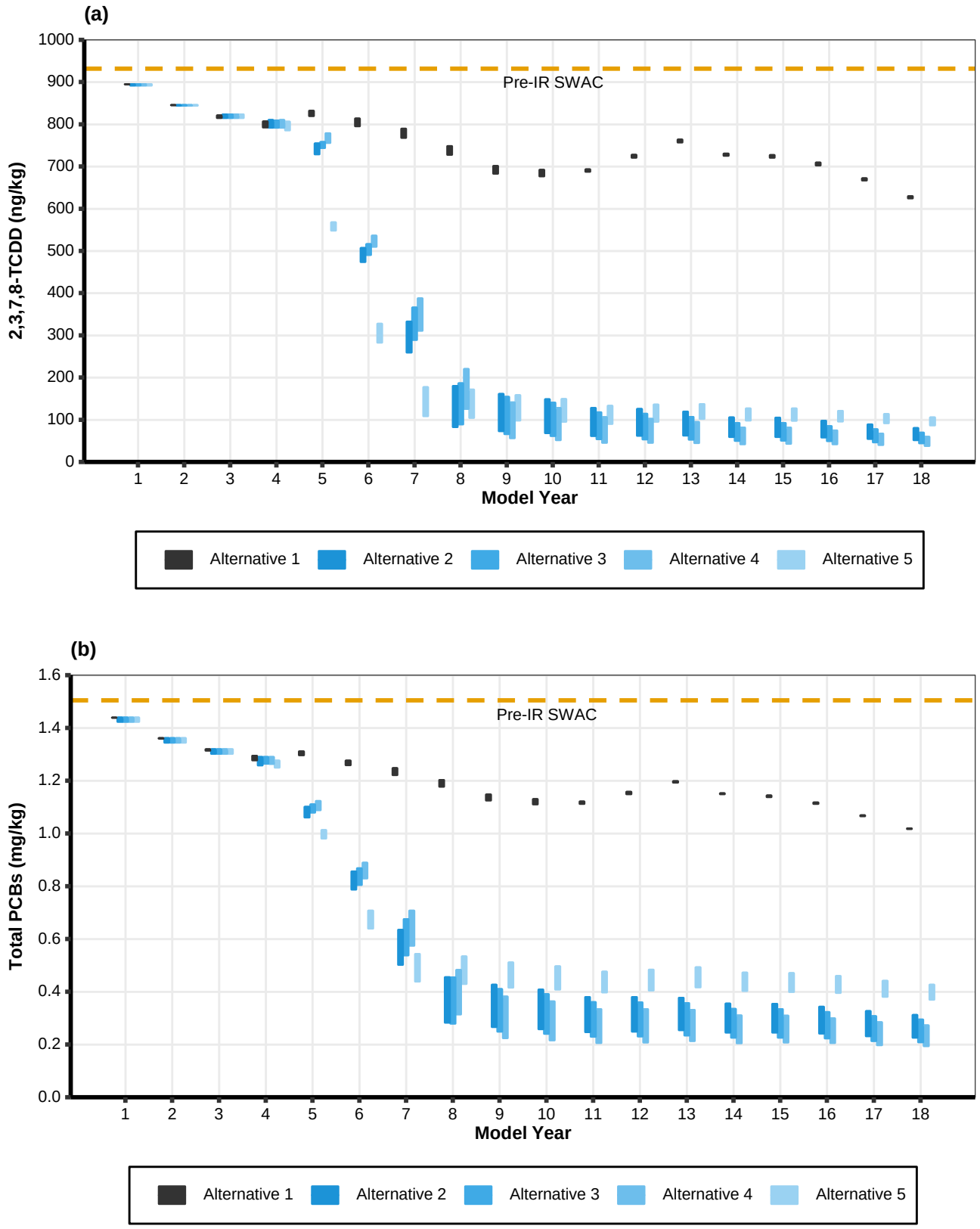
Figure 12b

Mapping Uncertainty Results for Alternative 3: Cumulative Water Column Downstream Load at RM 8.3 for Total PCBs

Upper 9-Mile Source Control Interim Remedy Feasibility Study

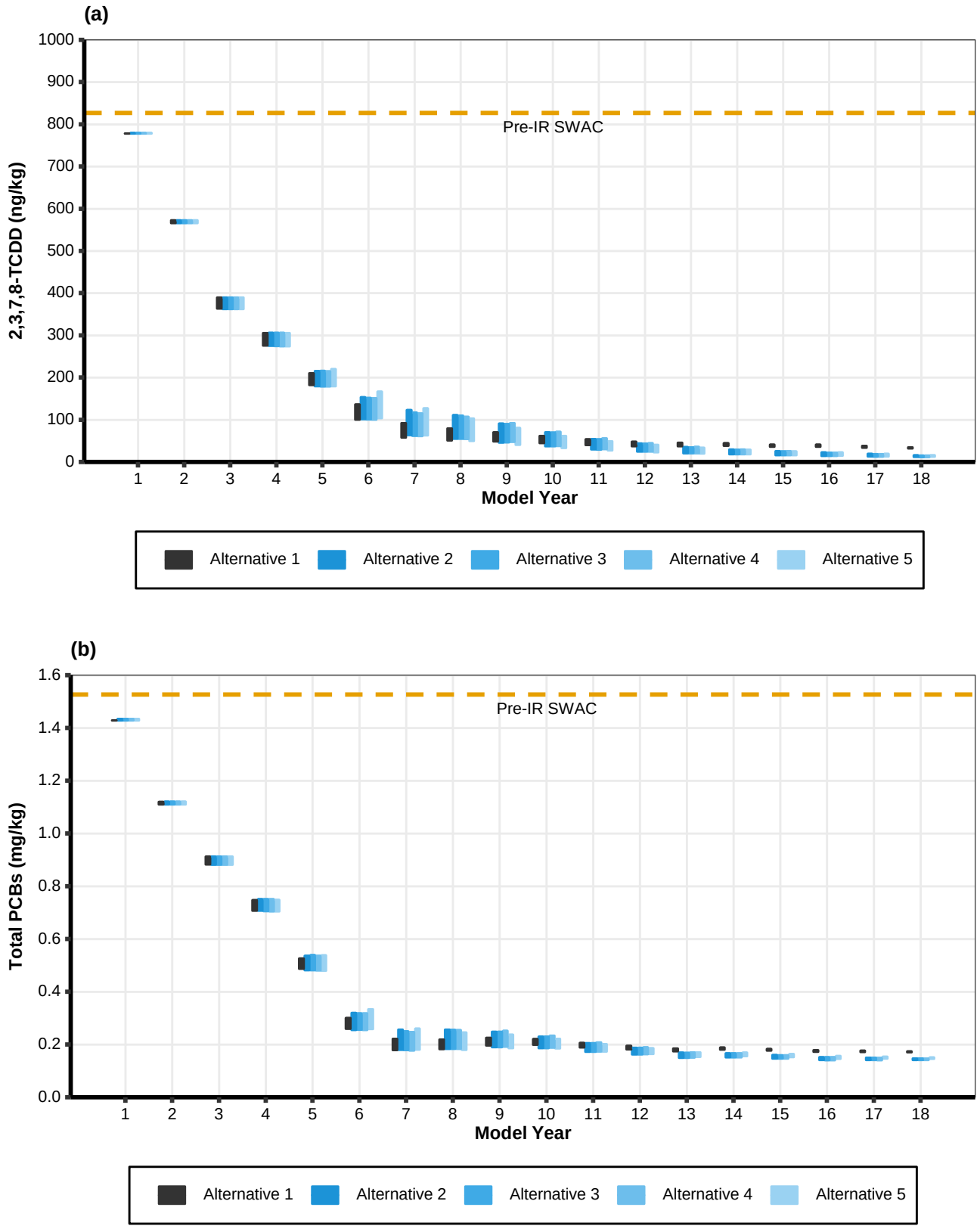
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

Attachment 1
Supplemental 18-Year IR FS Model Projection Time Series



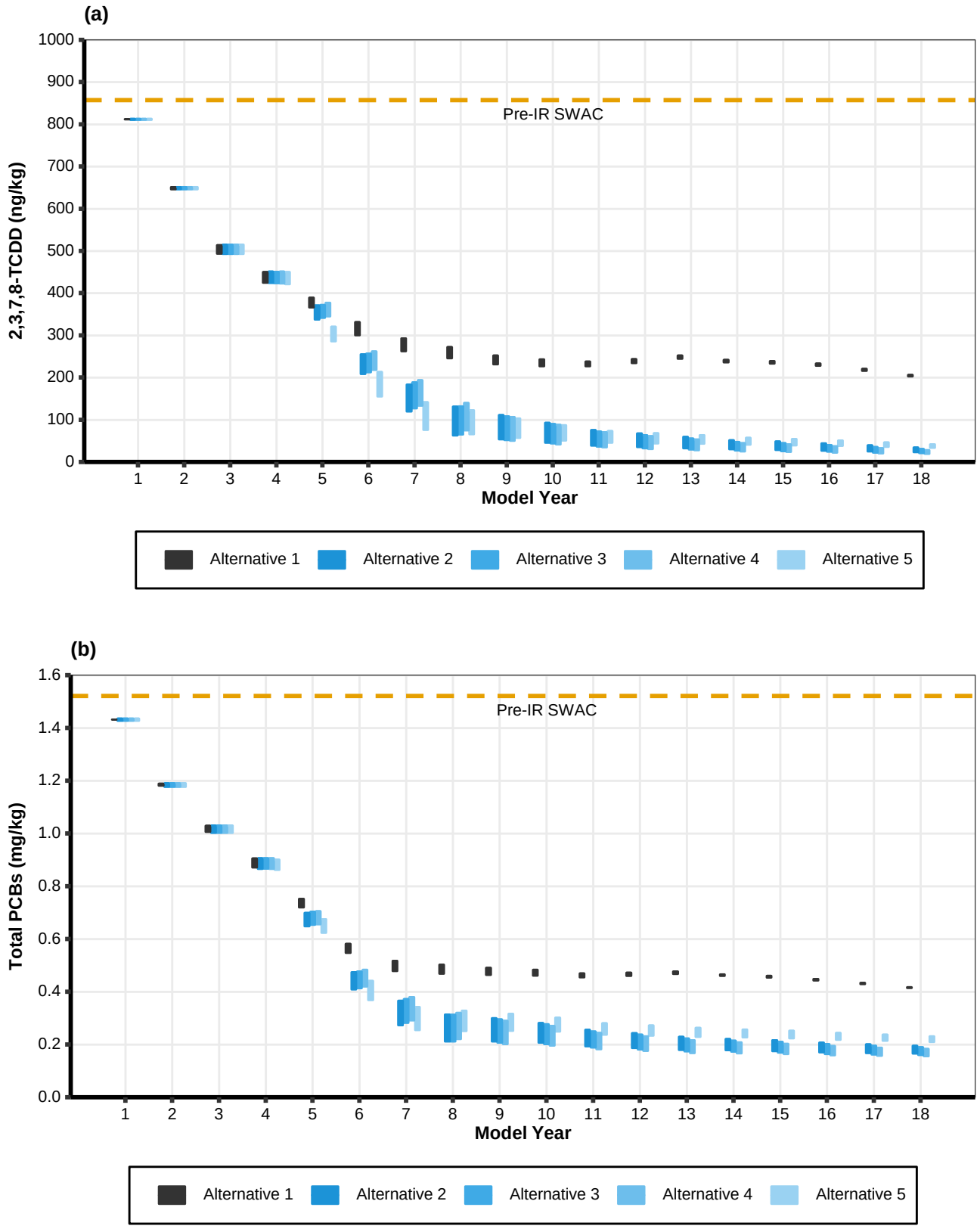
Note: Initial SWACs based on CS 37. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 1.
Projected SWAC of (a) 2,3,7,8-TCDD and (b) Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



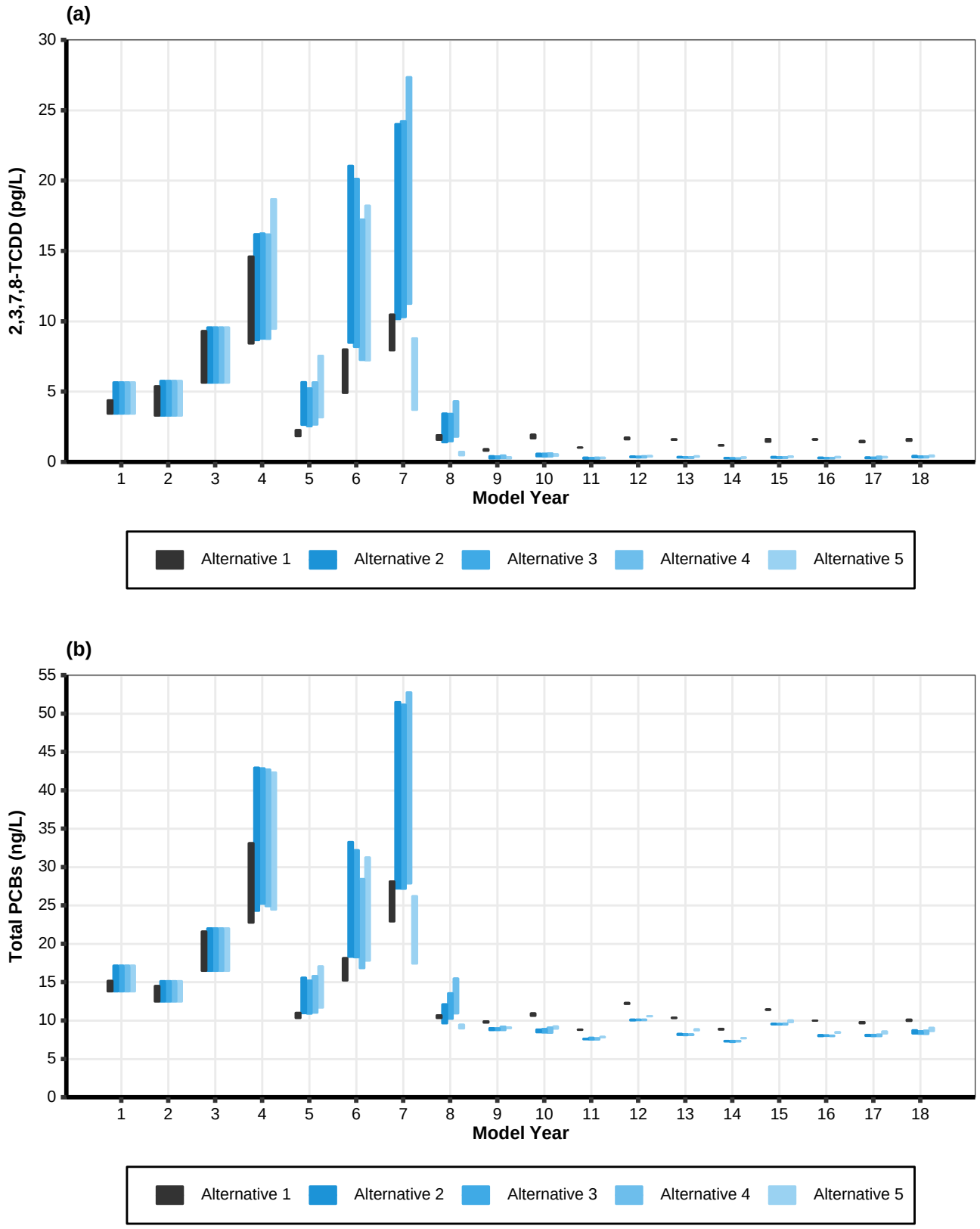
Note: Initial SWACs based on CS 37. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 2.
Projected SWAC of (a) 2,3,7,8-TCDD and (b) Total PCBs in RM 0 to RM 8.3
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



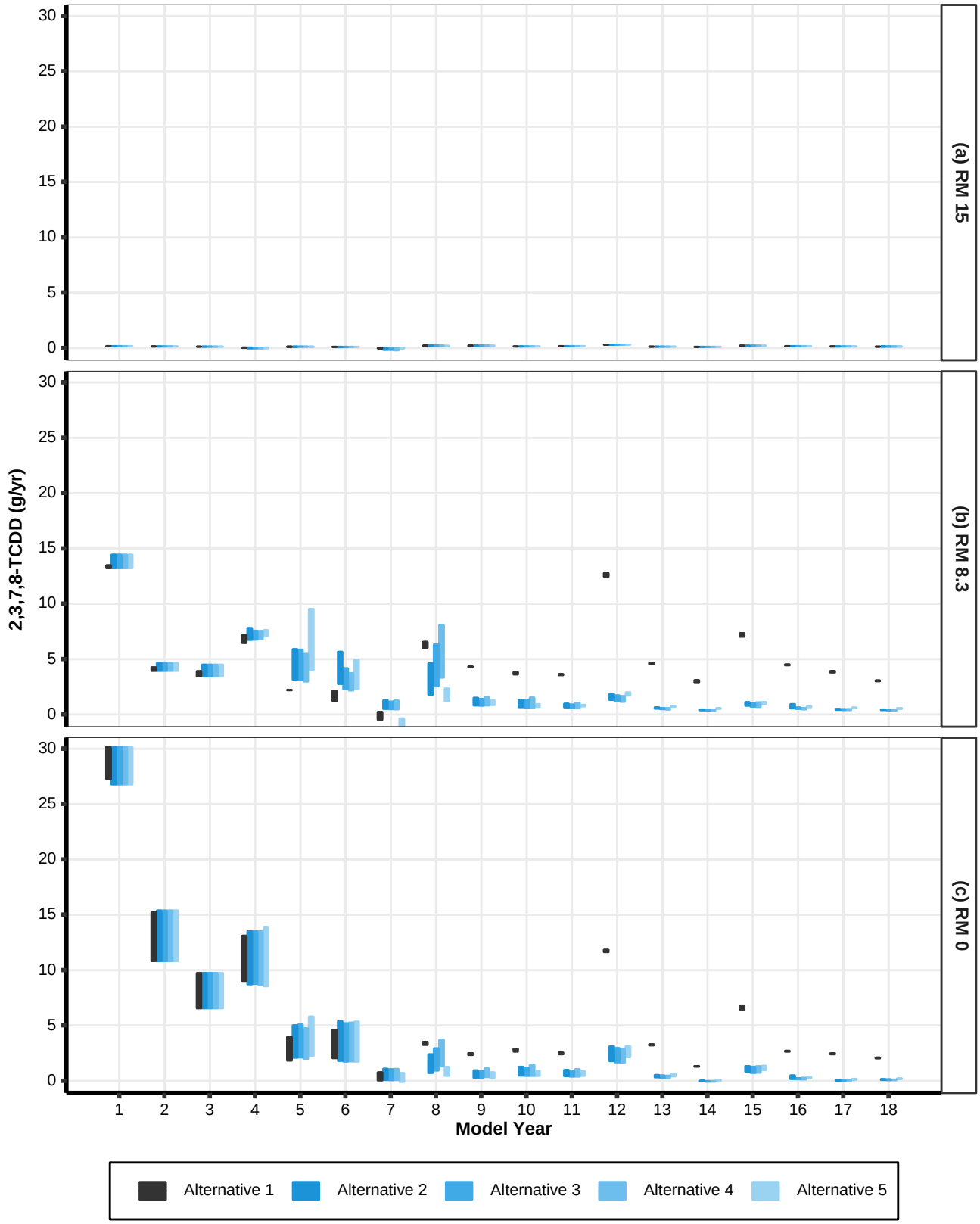
Note: Initial SWACs based on CS 37. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 3.
Projected SWAC of (a) 2,3,7,8-TCDD and (b) Total PCBs in RM 0 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



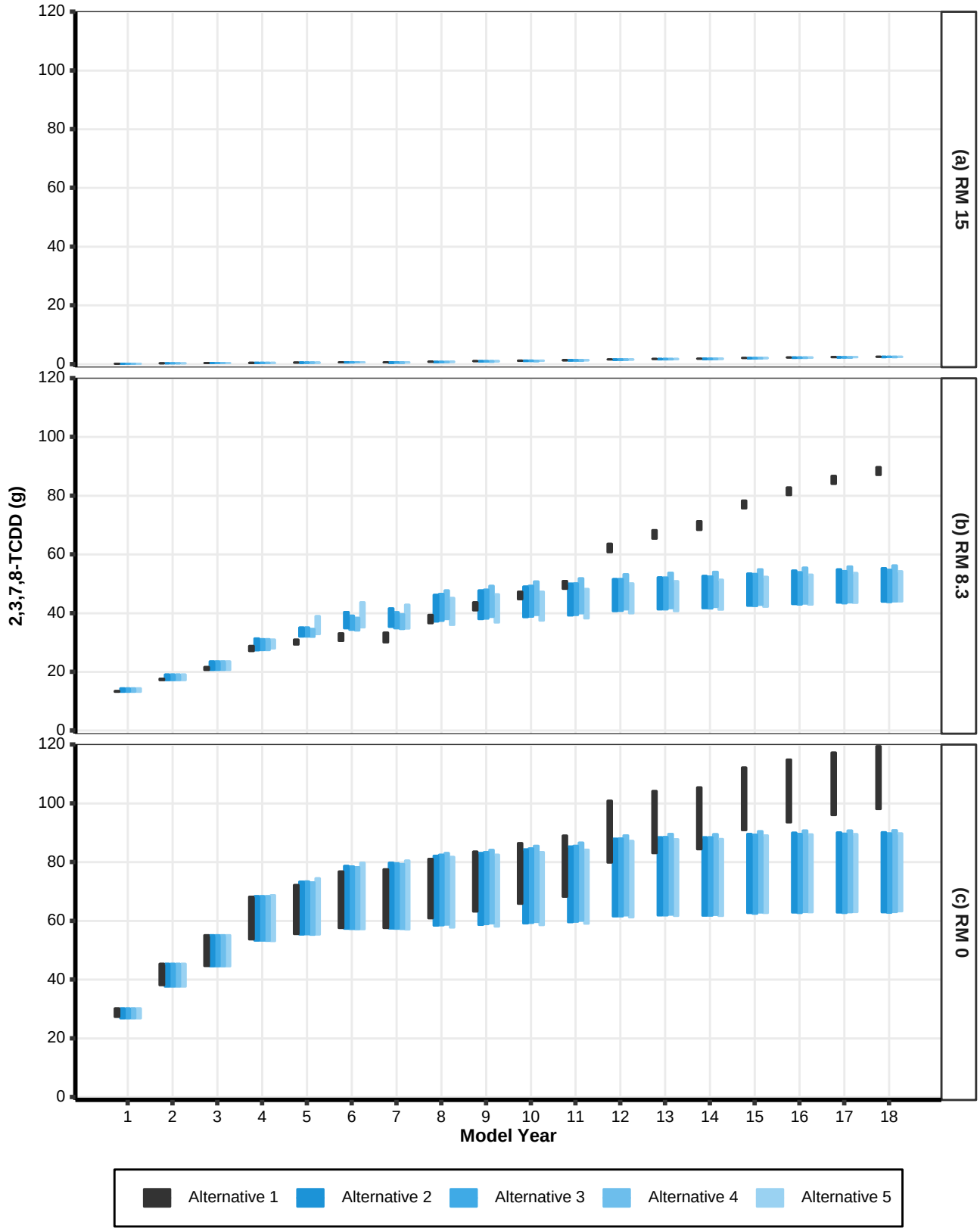
Note: Boxes represent projected range of sensitivity to selected model input parameters.

Figure 4.
Projected Water Column Concentration of (a) 2,3,7,8-TCDD and (b) Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



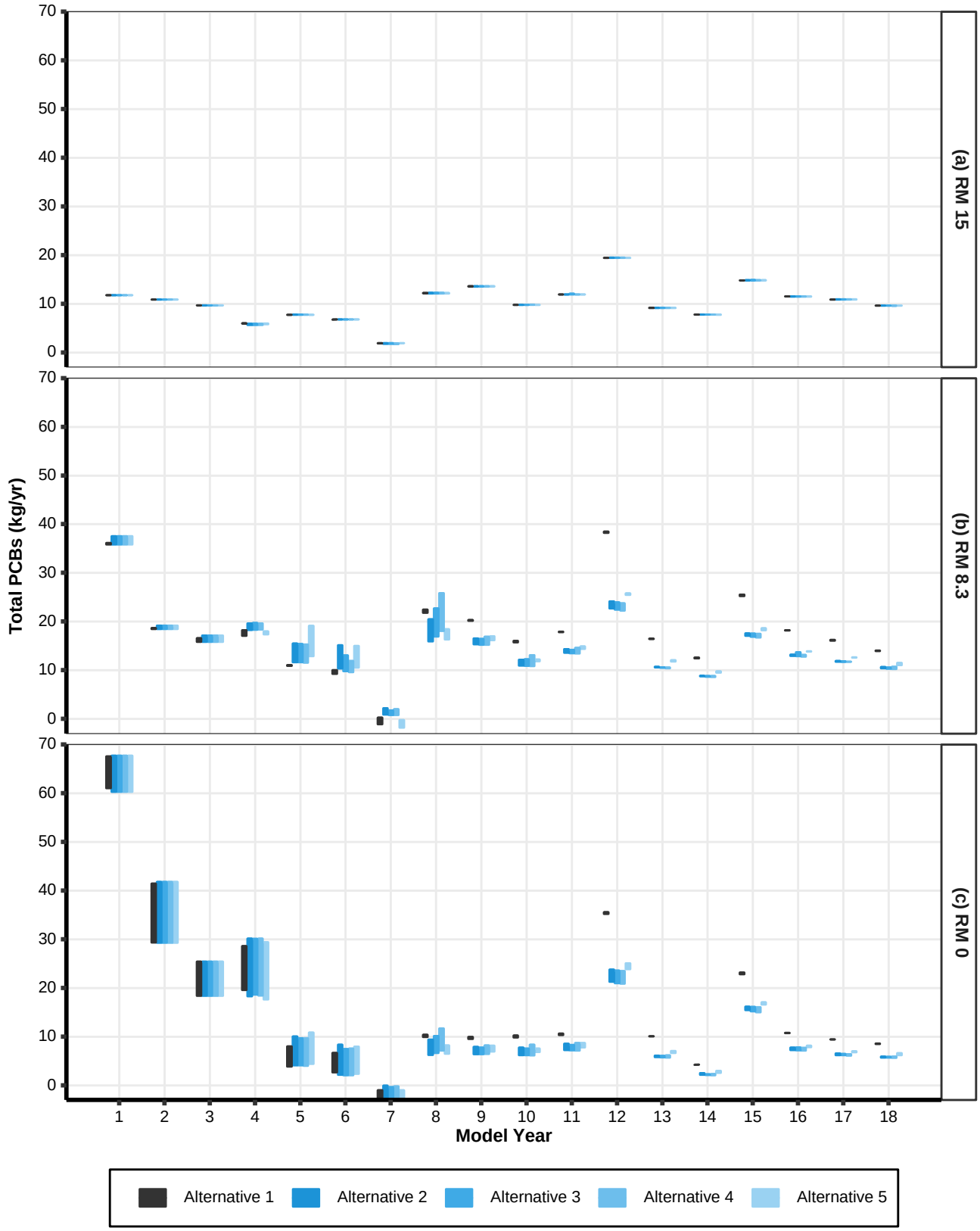
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 5.
Projected Water Column Downstream Load of 2,3,7,8-TCDD at (a) RM 15, (b) RM 8.3, and (c) RM 0
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



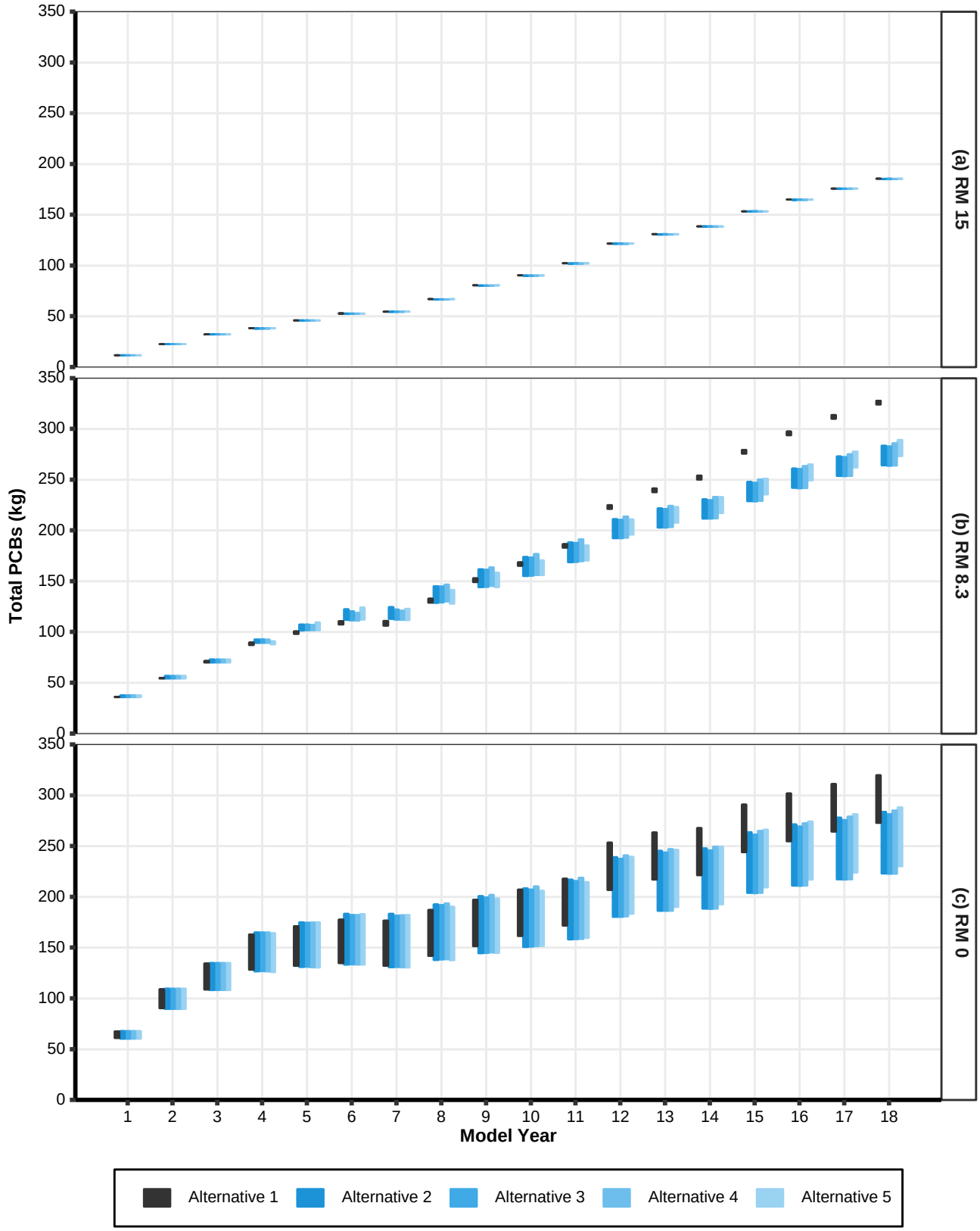
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 6.
Projected Cumulative Water Column Downstream Load of 2,3,7,8-TCDD at (a) RM 15, (b) RM 8.3, (c) RM 0
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



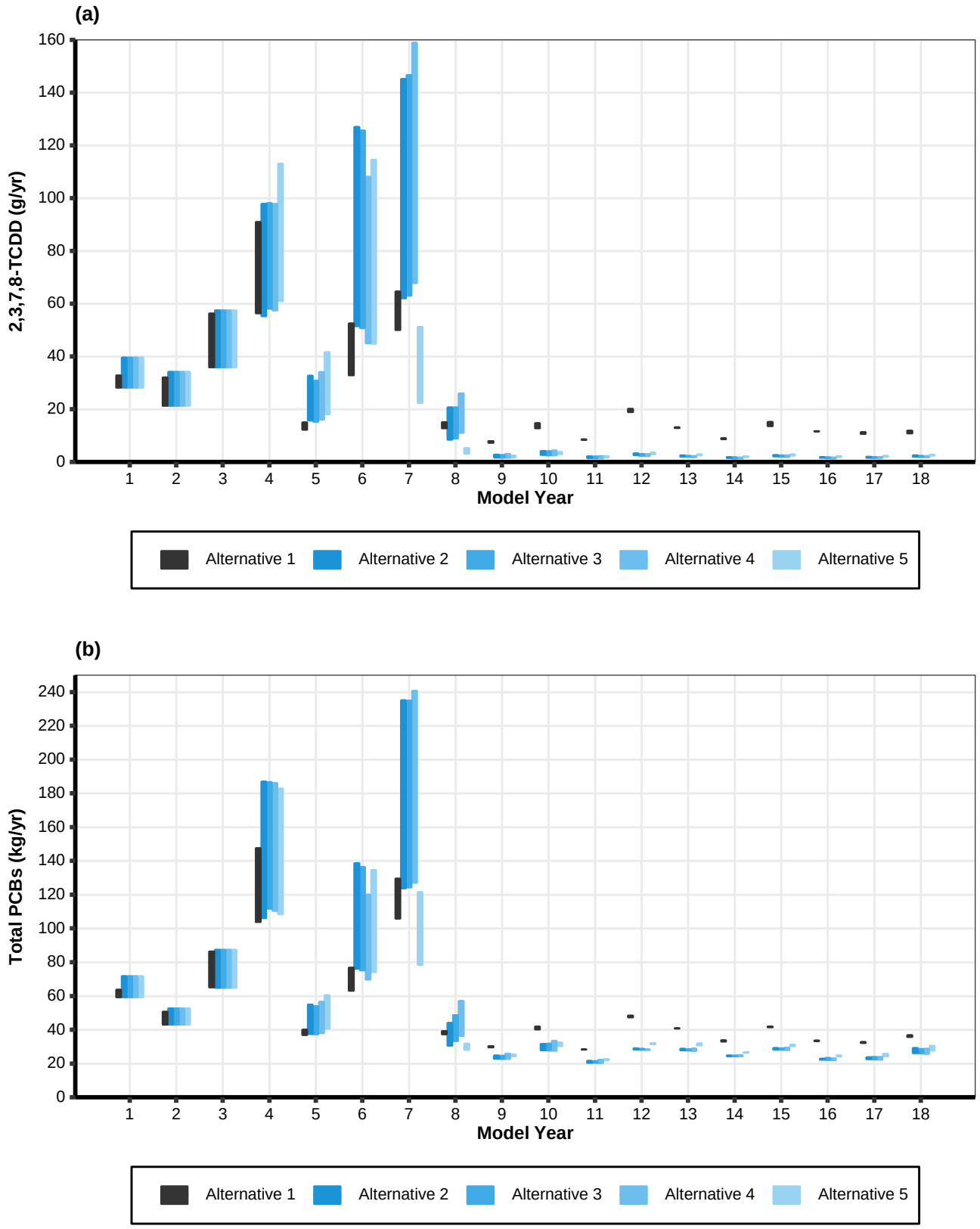
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 7.
Projected Water Column Downstream Load of Total PCBs at (a) RM 15, (b) RM 8.3, and (c) RM 0
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



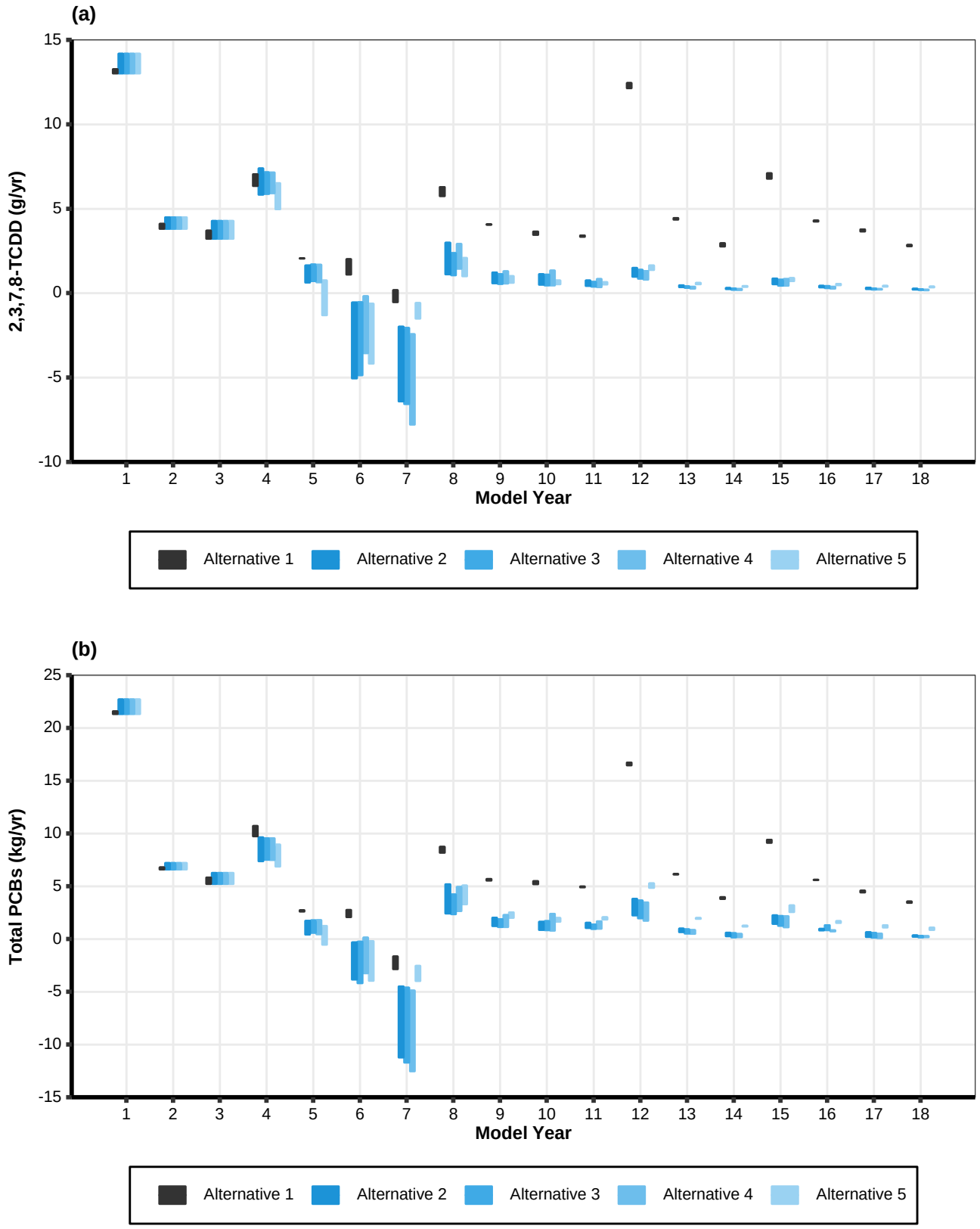
Note: Positive load denotes downstream direction. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 8.
Projected Cumulative Water Column Downstream Load of Total PCBs at (a) RM 15, (b) RM 8.3, (c) RM 0
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note: Boxes represent projected range of sensitivity to selected model input parameters.

Figure 9.
Projected Gross Erosional Flux of (a) 2,3,7,8-TCDD and (b) Total PCBs in RM 8.3 to RM 15
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note: Negative values indicate erosion, while positive values indicate deposition. Boxes represent projected range of sensitivity to selected model input parameters.

Figure 10.
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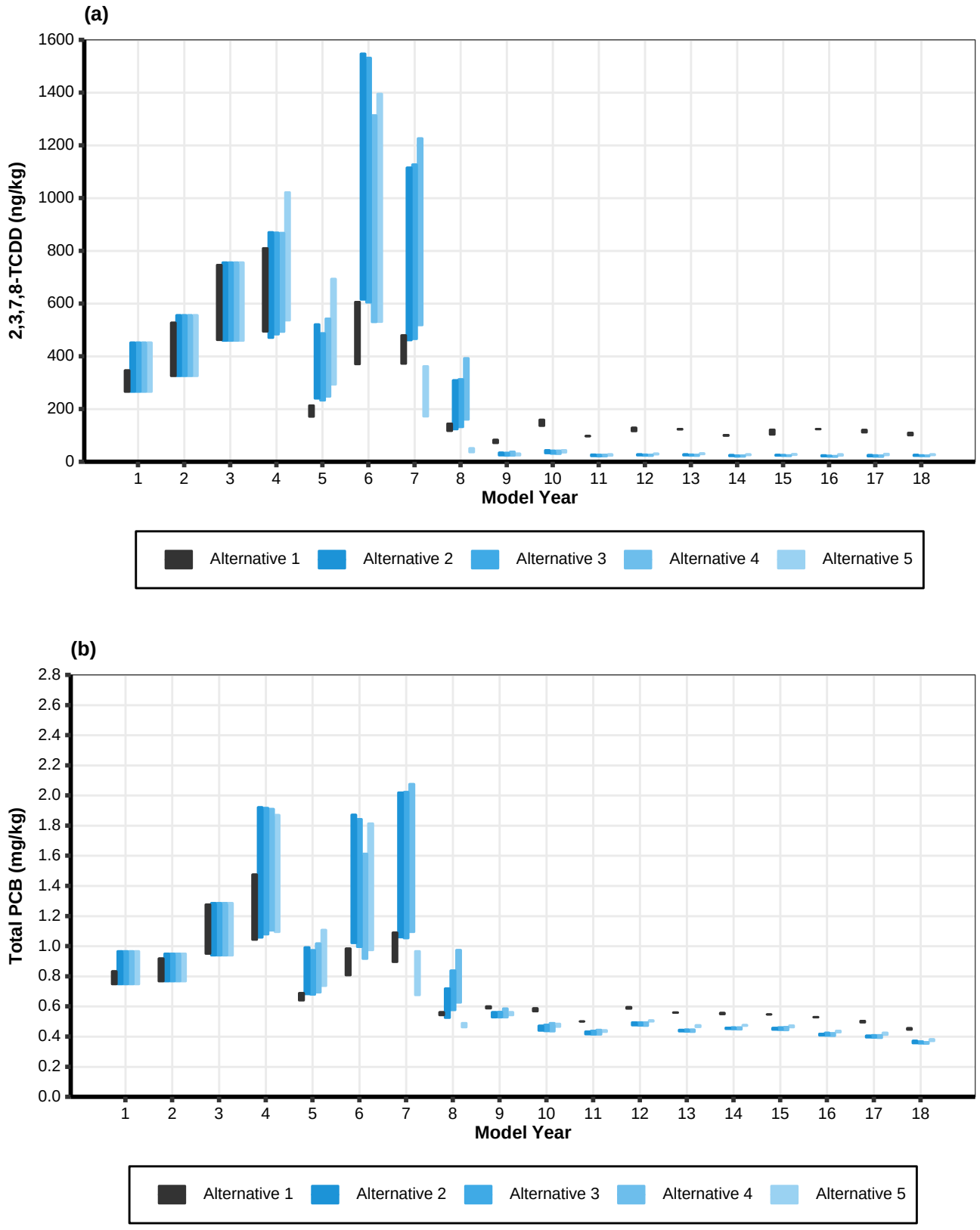
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



Note: Boxes represent projected range of sensitivity to selected model input parameters. Concentrations are computed as the ratio of total chemical deposition flux to total cohesive sediment deposition flux over one year periods.

Figure 11.
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Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

APPENDIX D
ADAPTIVE MANAGEMENT IMPLEMENTATION APPROACH FOR THE LOWER PASSAIC RIVER STUDY AREA

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

Prepared for
Lower Passaic River Cooperating Parties Group
New Jersey

Prepared by

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
ARAR	applicable or relevant and appropriate requirement
BMP	best management practice
CERLCA	Comprehensive Environmental Response, Compensation and Liability Act
CFT	contaminant fate and transport (model)
COC	chemical of concern
CPG	Lower Passaic River Cooperating Parties Group
CSM	conceptual site model
CSTAG	Contaminated Sediments Technical Advisory Group
DDE	4,4′-dichlorodiphenyldichloroethene
DDT	4,4′-dichlorodiphenyltrichloroethane
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FWM	food web model
HST	hydrodynamic/sediment transport (model)
IR	interim remedy
LiDAR	light detection and ranging
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
MNR	monitored natural recovery
NJDEP	New Jersey Department of Environmental Protection
OU	operable unit
PCB	polychlorinated biphenyl
PDI	pre-design investigation
PRG	preliminary remediation goal
RAL	remedial action level
RAO	remedial action objective

RD	remedial design
RG	remediation goal
RI	remedial investigation
ROD	record of decision
SWAC	surface area-weighted average concentration
SWQS	surface water quality standard
TI waiver	technical impracticability waiver

1 INTRODUCTION

Consistent with the goals of the U.S. Environmental Protection Agency (EPA) Superfund program, the overall objective of adaptive management for the Lower Passaic River Study Area (LPRSA, or site) is to ensure the attainment of risk-protective conditions for the site as expeditiously and cost-effectively as possible. To meet this objective, remedial action for the upper 9 miles of the LPRSA will be adaptively managed under a multistep process. The first step would be the design and implementation of a source control interim remedy (IR) for the upper 9 miles.[1] An IR would be followed by a period of recovery assessment monitoring[2] to evaluate the response of the system to an IR and track the recovery of sediment, the water column, and biota to risk-protective conditions. Based on the evaluation of monitoring data and consideration of any final remedial requirements, EPA would issue a final Record of Decision (ROD)[3] to establish risk-based remediation goals (RGs) and specify any additional actions beyond an IR that may be needed to attain the RGs and address remaining site risks.

The conceptual basis of an IR is to reduce the impact of source sediment in the upper 9 miles of the LPRSA that, through erosion, deposition, and other processes, limits recovery of the river. As described in the IR Feasibility Study (FS), these sources have high contaminant concentrations, have a low potential for recovery, and act as a reservoir for potential migration of contamination to surface water and biota. An IR would remove the majority of the highly contaminated sediment in the upper 9 miles, reduce the surface area-weighted average concentration (SWAC) of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) by more than 90 percent and allow evaluation of the recovery of sediment, surface water, and biota once these sources are removed. Removal of these sources would also reduce the SWAC of total polychlorinated biphenyls (PCBs) by more than 80 percent, and reduce the SWACs of other collocated contaminants. Reducing the 2,3,7,8-TCDD SWAC by more than 90 percent is expected to enhance the rate of recovery in the river and allow a more detailed evaluation of the sediment/biota interaction following IR implementation.

This Adaptive Management Implementation Approach presents a structured program for identifying key uncertainties that limit the understanding and therefore the remediation of sediment in the upper 9 miles of the LPRSA and surface water throughout the LPRSA. The data that would be collected prior to, during, and following an IR would guide the planned

[1] Other actions have been performed in the LPRSA that have generated information that has facilitated learning about the system and ongoing adaptive management. These other actions include the Phase 1 removal at the Lister Avenue facility and the RM 10.9 removal action.
[2] Recovery assessment monitoring is part of the LPRSA long-term monitoring program.
[3] It is anticipated that the final ROD would address all remaining site risks for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA.

multistep remedial action for the upper 9 miles. The outcome of the process would answer the critical overarching question:

> *What actions are required to promote and attain the overall protection of human health and the environment, initially for the upper 9 miles of the LPRSA and subsequently for the entire LPRSA?*

1.1 ADAPTIVE MANAGEMENT GOALS AND DEFINITIONS

Adaptive management is a systematic, learning-based process meant to support effective and transparent project decision-making, reduce uncertainties, utilize resources efficiently, build stakeholder consensus, and improve project outcomes. It is based on a model of defining, testing, and refining key hypotheses regarding the behavior of a system and its expected response to management actions (DOI 2009; NAS 2004). For complex, large-scale sediment remediation projects such as the LPRSA, adaptive management can play a central role in several important ways:

- Further developing and refining the conceptual site model (CSM) and quantitative models of system behavior, including recovery processes
- Reducing uncertainty in remedial decision-making by learning from new information and data that become available through site investigation, remedy design and implementation, and monitoring
- Testing and evaluating the response of the system to remedial actions
- Modifying key hypotheses on system behavior and/or associated response actions, when needed, to support remedy selection and attainment of final RGs.

Adaptive management focuses on developing a well-founded understanding of the system as expressed through the CSM, improving this understanding over time through further investigation and evaluation of system responses, and establishing a decision-making framework that relies on new learnings to improve project outcomes. In addition, an adaptive management program may incorporate standard elements of remediation projects—such as undertaking engineering design studies, preparing plans and specifications, conducting value engineering, and developing contingency plans—that may result in significant adaptations to the design approach, overall scope of the remedial action, selection of means and methods for construction, and construction activities.

In 2017, EPA's Superfund Task Force published recommendations to expedite the cleanup process at Superfund sites, which included promoting the use of adaptive management at large and/or complex sites and expediting cleanups through use of early/interim RODs and removal actions (USEPA 2017). A July 2018 EPA memorandum provides the following working definition of adaptive management for Superfund projects (USEPA 2018a):

> Adaptive management is a formal and systematic site or project management approach centered on rigorous site planning and a firm understanding of site conditions and uncertainties. This technique, rooted in the sound use of science and technology, encourages continuous re-evaluation and management prioritization of site activities to account for new information and changing Site conditions. A structured and continuous planning, implementation and assessment process allows EPA, states, other federal agencies (OFAs), or responsible parties (PRPs) to target management and resource decisions with the goal of incrementally reducing site uncertainties while supporting continued site progress.

1.2 ADAPTIVE MANAGEMENT FOR THE UPPER 9 MILES OF THE LPRSA

In 2017, the Lower Passaic River Cooperating Parties Group (CPG) initiated discussions with EPA on an adaptive management program for the LPRSA. The first step would be an IR for sediment in the upper 9-mile reach of the LPRSA to control sources that are inhibiting recovery of the river. Following the CPG proposal, a series of discussions was held between EPA, the CPG, and the New Jersey Department of Environmental Protection (NJDEP) to develop the details of an IR. In February 2018, an EPA-sponsored Contaminated Sediments Technical Advisory Group (CSTAG) review was conducted on the rationale for a source control IR, which would be implemented as the initial step in a remediation program for the upper 9 miles of the LPRSA and guided by adaptive management principles. Following stakeholder meetings and CSTAG review and comments (USEPA 2018b), EPA determined that an IR, as part of an adaptively managed remediation program for the upper 9 miles of Operable Unit (OU) 4 of the Diamond Alkali Superfund Site, should be evaluated in an IR FS[4]:

> Accordingly, EPA has discussed with the CPG an adaptive management strategy based on an iterative approach to address sediment source areas in the upper nine miles of the LPRSA, while collecting additional information to reduce uncertainties associated with that reach of the river…. EPA anticipates that any remedy selected as an interim remedy will utilize adaptive management principles which will include monitoring requirements, metrics for interim remedy performance, triggers for further action, and steps to be taken to ensure adequate progress toward final risk-based remedial goals. (USEPA 2018c)

Following submittal of the draft IR FS to EPA, a second CSTAG review was conducted in November 2019. The subsequent January 31, 2020, CSTAG recommendation memo further supported an adaptive management approach to remedial action in the upper 9 miles, recognizing the uncertainty in the outcomes of potential management actions and the importance of a monitoring program that would "identify the response and trends in parameters associated with progress toward and attainment of RAOs while providing a better understanding of the drivers of or impediments to attaining the objectives." (USEPA 2020a)

The EPA-approved IR FS work plan for the upper 9 miles (Integral 2019) recognized that an IR, if implemented, would be a component of the adaptive management approach for the remediation of the upper 9 miles of the LPRSA. The work plan further specified that the IR FS present a framework for an adaptive management program, including types of performance

[4] OU4 consists of the entire 17.4-mile LPRSA. OU1 (the former Diamond Alkali site at 80-120 Lister Avenue) and OU2 (the lower 8.3 miles of the LPRSA) lie within the boundaries of OU4. OU3 encompasses Newark Bay.

metrics that may be applied to assess long-term recovery of the river following completion of an IR, data that would be used to evaluate recovery relative to performance metrics, decision points, and alternative response actions. This Adaptive Management Implementation Approach provides a detailed framework to address that requirement, as well as the CSTAG recommendations (USEPA 2018b, 2020a) and EPA Region 2 responses to CSTAG recommendations (USEPA 2018d, 2020b). The structure of this appendix was developed by considering the pilot template for an adaptive management project management plan currently under development within EPA.

Because the planning process for a source control IR is currently in the IR FS stage, this version of the Adaptive Management Implementation Approach is a first iteration that is expected to be revised and expanded into a more comprehensive plan as project planning, design, and implementation progress. It is anticipated that the approach (and comprehensive plan, as available) will be refined and expanded during the remedial design (RD) and at the initiation of recovery assessment monitoring, at minimum, as data and information become available to add details to support evaluations and decision-making or when new guidance is issued. The fundamental framework of the Adaptive Management Implementation Approach, as described in this document, would not be subject to future refinements or modifications.

2 SCOPE AND ROLE OF ADAPTIVE MANAGEMENT FOR THE UPPER 9 MILES OF THE LPRSA

Adaptive management provides a number of opportunities to optimize the benefits of a phased approach to the remediation of the upper 9 miles of the LPRSA. A source control IR would remove internal sediment sources of 2,3,7,8-TCDD and total PCBs, along with other collocated chemicals of concern (COCs), within the upper 9 miles. Under the CSM, these sources are understood to limit the natural recovery of the upper 9 miles, and also confound the ability to evaluate future sediment/biota interactions following their removal (i.e., relationships between sediment and tissue concentrations may be affected by a source control action). An IR would be designed and implemented to fulfill the IR remedial action objectives (RAOs), and meet the requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Based on the results of recovery assessment monitoring, adaptive management would support effective and efficient mitigation of risks through a final ROD that establishes final RGs and through ultimate verification of the attainment of risk-protective conditions.

Through a systematic approach to collection and evaluation of the recovery assessment monitoring data, the key site uncertainties that currently preclude selection of a final remedy would be reduced, allowing any further remedial action(s) that may be necessary to reach risk-protective final RGs to be identified and implemented with greater certainty, based on new information and application of a clear decision framework.

The adaptive management program for the upper 9 miles of the LPRSA would begin with a ROD for a source control IR. Adaptive management considerations would be initiated during the IR design phase, when initial preliminary remediation goals (PRGs) and expected recovery trajectories would be established, and continue through recovery assessment monitoring to assess system response and track progress toward attaining (and potentially

Key Terms and Tools Used in the Upper 9-Mile LPRSA Adaptive Management Implementation Approach

Adaptive Elements

- Identify key project activities with decision points that may trigger an adaptive response
- Address primary decision questions based on testable hypotheses

Decision Trees

- Identify critical information inputs and decision points for each adaptive element
- Specify general response options at each decision point

Timelines

- Relate the adaptive elements to other major project milestones and CERCLA administrative requirements
- Address alternate scenarios for long-term performance

refining) PRGs, issuance of a final ROD, and, ultimately, confirmation of the attainment of final RGs. Ongoing current conditions monitoring and several other planned sampling activities, outlined in Section 2.4 of this appendix, provide key information inputs for adaptive management decision-making throughout the program.

Risk-based PRGs for the upper 9-mile reach would be developed in parallel with the RD phase of an IR. These PRGs would be used to evaluate system recovery following the IR. As stated in EPA Region 2's response to CSTAG's second review, "*…the evaluation will be conducted within the overall adaptive management framework and will include constraining uncertainties in PRG inputs so final RGs can be identified…*" (USEPA 2020b). As such, the PRGs may be modified over time as new information becomes available to reduce uncertainties in the key inputs cited by EPA. This is consistent with EPA guidance that recognizes refinement of PRGs during the CERCLA process.[5]

Following IR implementation and a period of monitoring, EPA would establish final RGs and would identify any additional action(s) needed to address remaining unacceptable risks for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA. These would be included in the final ROD.

The sidebar on the previous page identifies the key terms and tools that are used throughout this Adaptive Management Implementation Approach. This appendix identifies three primary adaptive elements of the project, as shown in Figure 2-1. The adaptive elements are key project activities and milestones that are accompanied by decision points that address the overarching goals of identifying information and/or actions that would support attainment of overall protectiveness and, as such, may trigger one or more adaptive responses. Each adaptive element identifies and addresses primary decision questions that are based on testable hypotheses and intended to guide management responses to new information at key project decision points. For each adaptive element, decision trees identify the critical information inputs needed to support project decision-making and to select the appropriate response options (e.g., diagnostic assessment, additional monitoring, additional response actions) that exist at each decision point for a range of possible circumstances. Finally, this appendix provides time lines that relate each adaptive element and its critical decision points to time frames for other project activities and for meeting CERCLA administrative requirements.

[5] "Preliminary remediation goals… may be revised… based on the consideration of appropriate factors including, but not limited to: exposure factors, uncertainty factors, and technical factors. Included under exposure factors are: the cumulative effect of multiple contaminants, the potential for human exposure from other pathways at the site, population sensitivities, potential impacts on environmental receptors, and cross-media impacts of alternatives. Factors related to uncertainty may include: the reliability of alternatives, the weight of scientific evidence concerning exposures and individual and cumulative health effects, and the reliability of exposure data. Technical factors may include: detection/quantification limits for contaminants, technical limitations to remediation, the ability to monitor and control movement of contaminants, and background levels of contaminants. The final selection of the appropriate risk level is made when the remedy is selected based on the balancing of criteria…" (USEPA 1991a)

Several project activities, including planned additional data acquisition and evaluation, improvements to the CSM, refinement of numerical models,[6] and the systematic evaluation of remedy implementation, remedy performance, and system recovery over time, would be used to address key uncertainties and inform adaptive management decisions throughout the course of the remediation of the upper 9 miles of the LPRSA. Relationships between the key uncertainties and the three adaptive elements addressed by this appendix are illustrated in Figure 2-2.

2.1 PROJECT STAKEHOLDERS

Major stakeholders that would be involved in the adaptive management process are identified in Figure 2-3. Effective and well-coordinated stakeholder participation is considered key to the successful implementation of adaptive management for the upper 9 miles of the LPRSA. Stakeholders would play various roles in adaptive management, which would involve their commitment of time, resources, and active engagement in project activities.

EPA Region 2, as the lead agency for the LPRSA, is responsible for the planning, implementation, and oversight of all response actions at the site, including adaptive management. EPA is also responsible for stakeholder communications and coordination of stakeholder activities. NJDEP is the designated support agency and provides consultation to EPA on response actions at the site. The federal trustees provide general review and feedback on response actions as well as oversight of resource protection. The entities responsible for implementing a source control IR on the upper 9-mile reach of the LPRSA would be formally identified as the "Performing Parties" in a Consent Decree or other CERCLA enforcement document. It is anticipated that the Consent Decree would also include requirements for recovery assessment monitoring and include provisions for adaptive management evaluations. The Performing Parties would be responsible for designing and implementing these actions. Local governments and the community would continue to participate in LPRSA response actions through the LPRSA Community Advisory Group and the public comment process on response actions that are proposed by EPA Region 2.

2.2 GENERAL DECISION FRAMEWORK

Adaptive management hinges on the ability to make appropriate decisions in response to new information, including newly collected monitoring data, revisions to the CSM, refined model projections, and/or better understanding of the key site uncertainties, as well as the ability to identify critical uncertainties and systematically plan for the collection of additional information to reduce the uncertainties (i.e., to systematically generate the new information needed). This appendix provides a systematic framework to guide decision-making in the context of adaptive

[6] The hydrodynamic, sediment transport, contaminant fate and transport, and food web models developed for the LPRSA are described in the Remedial Investigation Report (AQEA 2019a).

management. This framework, introduced conceptually in Table 2-1 and developed further throughout this appendix, links each adaptive element and its associated decision question to the relevant time frame(s) for decisions, key data inputs, and decision-making criteria and supporting analyses.

The adaptive management decision framework is intended to support transparent and efficient decision-making for adaptive management. Decisions would be made in accordance with the following general principles:

- The decision frameworks for the adaptive elements presented in Sections 3 through 5 are intended to identify the broad parameters and requirements for decision-making for adaptive responses to new information and/or changing site conditions.
- The decisions to be made as part of adaptive management would be informed by the key information inputs that are identified in this appendix. The decision frameworks for the adaptive elements identify how the information inputs would be assessed and, where appropriate, integrated into an evaluation using multiple lines of evidence.
- The decision frameworks identify clear decision time frames for each adaptive element, in relation to the overall project time line and CERCLA administrative requirements for the LPRSA.
- While it is impossible to foresee all of the factors that may be relevant to a particular decision, the decision frameworks provide an overall structure for identifying appropriate response actions, considering the overall facts and circumstances that surround each decision point.
- Project stakeholders would participate in evaluating new information and providing input to decision makers on appropriate adaptive responses, when needed. When a critical decision point is reached, it is assumed that stakeholders and decision makers would abide by the guidelines and decision protocols identified in this appendix for each adaptive element to the maximum extent reasonably possible.

These general principles apply to each of the three adaptive elements addressed by this appendix.

2.3 PROJECT TIME LINE

A general project time line for the planning, design, and implementation of a source control IR for the upper 9 miles, along with recovery assessment monitoring and adaptive management, is shown in Figure 2-4 (assuming a best-case scenario where the final ROD does not require any further action, only continued monitoring of ongoing recovery towards no further action). Following implementation of a source control IR, it is assumed that EPA's formal determination of remedy completion would occur within approximately 3 years; this time period would include necessary sampling and evaluation to determine remedy completion. (Appendix H of

the IR FS presents the remedy completion assessment framework for a source control IR.) In the bottom portion of Figure 2-4, major decision points associated with the three adaptive elements are identified. Additional details related to the time lines for the three main adaptive elements of the project and the potential schedule implications associated with a range of possible decision outcomes are presented in Sections 3 through 5 of this appendix.

2.4 SAMPLING ACTIVITIES AND OBJECTIVES TO SUPPORT ADAPTIVE MANAGEMENT

Sampling and monitoring activities that have been performed to support the remedial investigation and feasibility study (RI/FS), those that are under way to characterize current conditions, and those that would be performed during RD, IR implementation, and recovery assessment monitoring would provide key information to support the implementation of adaptive management in the upper 9 miles of the LPRSA. The RI performed for the 17-mile LPRSA (AQEA 2019a) provided the foundational data and system understanding to support an initial evaluation of an IR. A summary of the RI is presented in Section 2 of the IR FS. The conceptual model of natural recovery in the upper 9 miles (Section 2.6 of the IR FS) provides the technical basis for an IR.

Additional data from several ongoing and anticipated sampling activities during the RD, implementation, and recovery assessment monitoring phases would supplement the existing data from the RI:

- A current conditions sampling program was initiated in 2019 and is expected to continue through 2020 and 2021, to provide information on pre-IR baseline site conditions.
- A pre-design investigation (PDI) would be implemented before the RD is conducted to define the final IR footprint and support other data needs to complete the RD.
- Construction performance monitoring would be performed during implementation of an IR to verify the attainment of construction performance criteria and confirm that construction best management practices (BMPs) are effective in meeting project criteria for controlling sediment resuspension and contaminant release.
- Construction completion sampling would be undertaken shortly after IR construction to support an evaluation of whether the IR was successful in attaining the IR RAOs.
- A recovery assessment monitoring program would be implemented following construction completion to evaluate system recovery, assess whether final RGs would be met within a reasonable time frame, and inform decisions regarding the need for and scope of any additional remedial actions that may need to be conducted.
- Long-term monitoring would be implemented to verify attainment of RGs and risk-protective conditions.

An overview of these additional sampling activities, which are anticipated to meet the data needs and objectives for the adaptive elements, is presented in Table 2-2 and described below.

2.4.1 Pre-Interim Remedy Baseline Conditions

The ongoing current conditions sampling program is intended to provide a thorough characterization of pre-IR physical, biological, and chemical baseline conditions in the upper 9 miles of the LPRSA. In addition to characterizing current conditions, these data would provide a basis for comparison with results of the future recovery assessment monitoring program. The current conditions sampling program is composed of the following components:

- Bathymetry and sediment texture survey
- Biota tissue chemistry
- Physical and chemical water column sampling.

Each of these components is briefly described below. Details are provided in the current conditions program Quality Assurance Project Plans (AQEA 2019b,c; Windward 2019b).

2.4.1.1 Bathymetry and Sediment Texture Survey

This survey was performed in 2019, and a data report is in preparation. The purpose of the survey was to obtain high-resolution bathymetry from bank to bank and characterize sediment texture. A combination of multibeam bathymetry and LiDAR was used for the bathymetric evaluation, including mudflats and other shallow areas not previously surveyed. Sediment texture was evaluated using side-scan sonar. Additional bathymetric survey(s) are anticipated prior to implementation of an IR for comparison with the 2019 survey to support identification of erosional and depositional areas in the upper 9 miles, including a survey following a high-flow event if such an event occurs. These data would be used in the RD and in the evaluation and modeling of system hydrodynamics and would support evaluation of erosional and depositional patterns for delineation of the remedial footprint to address RAO 2.

2.4.1.2 Biota Chemistry

The current conditions biota sampling (Windward 2019b) is a multiyear program to characterize baseline COC concentrations in fish and crab tissue. The degree of sampling success and results of the first year of sampling will be used to adapt and optimize the scope of the second year of sampling. Year 1 biota sampling targeted seven primary species over two river reaches in the upper 9 miles of the Lower Passaic River (LPR). The general objectives for this sampling are to:

1. Collect sufficient biota data to enable the comparison of pre- and post-IR biota COC concentrations

2. Evaluate and, as necessary, refine the food web model (FWM) to better represent the relationship (i.e., transfer of contaminants) between sediment and biota (e.g., fish and blue crabs)
3. Identify and refine specific characteristics of biota (e.g., species abundance, COC concentrations, and required sample size) within the upper 9 miles of the LPR to support refinement of the current conditions program for year 2 of the program and development of the recovery assessment monitoring program.

2.4.1.3 Physical and Chemical Water Column

The physical and chemical water column programs (AQEA 2019b,c) are generating data to support the design, implementation, and evaluation of the IR.

The physical water column program includes collection of flow velocity, turbidity, conductivity, and temperature data continuously at five fixed-location stations and periodically at cross-river and along-river transects. Periodic sampling is timed to collect data over a range of flow conditions, including a high-flow event (>5,000 cubic feet per second) assuming such an event occurs and sampling can be conducted safely.

The chemical water column program includes both small- and high-volume sample collection. This sampling effort utilizes the same sampling locations as those used for the physical water column sampling. Chemical water column sampling is performed periodically to capture a range of flow conditions and opportunistically to capture a high-flow event (if such an event occurs and sampling can be conducted safely).

The physical and chemical water column sampling programs will achieve the following objectives:

1. Establish the current key physical characteristics (flow velocity, turbidity, suspended solids, salinity, and temperature), including their spatial and temporal variation, within the upper 9 miles of the LPR. These data would support the design of an IR, including the types of resuspension controls that will be used.

2. Characterize the relationship between hydrodynamic conditions and concentrations of suspended sediment and COCs, including spatial and temporal variation, in the water column within the upper 9 miles of the LPR. These data would be used to refine numerical models and will be compared to recovery assessment monitoring data to evaluate the success of an IR in reducing COC water column concentrations.

3. Support the calibration and refinement of the hydrodynamic/sediment transport (HST) and contaminant fate and transport (CFT) models. These data will be used to predict post-IR recovery trajectories during the RD.

2.4.2 Pre-Design Investigation

Before the RD is prepared, a comprehensive PDI would be conducted. The PDI would include a phased sediment sampling program to develop and refine the IR remedial footprint. It is anticipated that the first phase would include sediment samples collected on a standardized grid pattern on approximately 80-ft centers. A second phase of sediment sampling would focus on areas selected to address uncertainty in the mapping of the sediment bed following the first phase of sampling and to better define the IR remedial footprint. The PDI may also include other sampling activities to support the RD (e.g., performing geotechnical evaluations, identifying utility crossings); any such activities would be determined during the planning phase of the PDI.

2.4.3 Interim Remedy Construction Performance and Construction Completion Monitoring

Construction performance monitoring would include bathymetric surveys to assess dredging cut lines and cap/backfill placement, sediment sampling to evaluate the residual management measures being employed,[7] and water column sampling to monitor solids and contaminant releases during implementation of an IR. If performance standards are exceeded, operational adjustments would be made to achieve the performance standards.

Sediment sampling would be performed following implementation of an IR to assess construction completion, as described in Appendix H.

2.4.4 Recovery Assessment Monitoring

Recovery assessment monitoring of contaminant concentrations in fish and crab tissue, the water column, and sediment would provide data needed to evaluate key metrics for the overall system recovery in response to the IR, to assess whether the CSM and quantitative models represent system behavior with sufficient accuracy and certainty to support overall project objectives, and to assess progress toward attainment of PRGs and RGs. While models would be used to predict recovery rates over time, the actual recovery trajectories, determined by the

[7] Limited sediment sampling would be performed after the completion of the first dredging season, targeting newly deposited sediment on top of capped areas, for the sole objective of evaluating the efficacy of dredging BMPs. The utility of the sediment sampling would be evaluated and discontinued after the first season if (a) sampling of newly deposited materials on capped surfaces proves impracticable, (b) the concentrations of newly deposited materials are consistent with or lower than near-field water column concentrations measured during active dredging, or (c) the variability and complexity of the system limits the ability to ascertain the cause of any elevated concentrations on the cap and consequently limits the ability to revise BMPs any further than what is concluded using the water column data. If sediment sampling is discontinued because water column concentrations are predictive of residual concentrations (item b, above) but significant and sustained non-compliance with water column performance standards directly related to dredging occurs after the discontinuation, additional sediment sampling may be triggered to evaluate BMP efficacy so long as earlier sampling found it to be practical and useful for BMP applications.

recovery assessment monitoring data, would be used to gauge whether system recovery is occurring in accordance with expectations for the response of the system to an IR.

Recovery assessment monitoring would include four components: biota, water column, sediment, and bathymetric surveys. Each of these components is described briefly below; details would be developed during the RD, taking into consideration the results of the current conditions sampling program and the PDI. Recovery assessment monitoring would be performed following completion of the IR until issuance of the final ROD, which would include provisions for continued long-term monitoring.

2.4.4.1 Biota

The monitoring of biota recovery is anticipated to include annual or periodic collection of fish and crab tissue, with selection of target species, numbers, size ranges, and locations based on the results of the current conditions sampling to best support assessment of tissue recovery and system response. The final data collection approach would be established during the RD. Tissue data would be analyzed for trends and compared to model projections to assess the adequacy of the CSM and the models to represent system response. Tissue data may also be used to monitor and evaluate attainment of interim risk-based thresholds for fish and crab tissue concentrations[8] and/or provide guidance on fish meal consumption, to communicate risk reduction expectations and progress to stakeholders over the course of the long-term recovery assessment.

2.4.4.2 Water Column

Water column monitoring is anticipated to include continuous and flow event-based physical water column monitoring, small-volume chemical water column monitoring, and passive sampling. Water column sampling would be performed annually or periodically during the recovery assessment monitoring period. The final scope and approach for recovery assessment monitoring would be established during the RD. Physical water column data would be used to support CSM and model refinement. Chemical water column data would be analyzed for trends to assess the effectiveness of an IR in reducing water column concentrations and compared to model projections to assess the adequacy of the CSM and the models to represent system response.

2.4.4.3 Sediment

Sediment sampling would be conducted to evaluate system response to an IR and support a diagnostic assessment if needed. It is anticipated that sediment sampling would be performed periodically during the recovery assessment monitoring period, following construction of the IR

[8] Interim risk-based thresholds have not been established, but may be considered in the future to support risk management and risk communication to the public.

to support the remedy completion evaluation (Appendix H), and periodically after completion of construction to evaluate ongoing reductions in sediment concentrations.

2.4.4.4 Bathymetry

Bathymetry surveys would be performed periodically to evaluate erosional and depositional behavior of sediment in the upper 9 miles, as well as following a high-flow event and/or to support a diagnostic assessment. The frequency of bathymetry surveys would be established following evaluation of the current conditions and pre-design bathymetry surveys, which should provide a better understanding of what magnitude of flow events and frequency of surveys would result in meaningful information.

3 ADAPTIVE ELEMENT 1: IR DESIGN AND IMPLEMENTATION

A source control IR—the initial step in the multistep remediation of the upper 9 miles of the LPRSA—was developed based on the CSM for the upper 9 miles of the LPR, as described in Section 2 of the IR FS. In summary, surface sediment with high concentrations of COCs is inhibiting recovery of the overall system by acting as a source of contamination that inhibits recovery elsewhere. Implementation of an IR would target the most significant sources of sediment contamination and would achieve a large reduction in sediment concentrations upon completion. The design and implementation of an IR would be managed to provide the best assurance that the IR RAOs are achieved and would be adapted throughout, as needed, to respond to new information.

Adaptive Element 1 includes activities and decision-making during IR design, implementation, and completion assessment to ensure achievement of the two RAOs identified in Section 3 of the IR FS. The IR completion assessment, presented in detail in Appendix H of the IR FS, integrates the activities of this element.

The IR design, implementation, and completion assessment would be supported by significant data collection efforts prior to, during, and following construction. These data would provide information for adaptive decision-making and support the development of five lines of evidence that would be used in the determination of IR completion:

1. The mapping of total PCB and 2,3,7,8-TCDD sediment concentrations and areas vulnerable to erosion and the use of that mapping to delineate areas to be remediated
2. The comprehensiveness of an IR design to address the identified sediment sources
3. The degree to which IR implementation comports with the design and effectively minimizes resuspension and redistribution of sediment
4. Attainment of the RAO by statistical evaluation of the post-IR confirmation sediment data
5. That the post-IR sediment data show no evidence of potential remaining source areas (i.e., no sediment above the remedial action level [RAL]) that exhibit the characteristics of being actionable per the decision framework presented in Appendix H.

Appendix H provides a full discussion of how these lines of evidence are incorporated in the remedy completion assessment framework. Described below is the planned adaptive management approach for IR design and implementation.

3.1 HYPOTHESIS 1.1: SEDIMENT SOURCES THAT INHIBIT SYSTEM RECOVERY CAN BE IDENTIFIED

The planned approach to delineating the IR footprint during the RD phase is based on current knowledge of COC concentration distributions and spatial variability, sediment stability/ erodibility, and river geomorphology. This information provides the foundation for the hypothesis that sediment sources that inhibit system recovery can be identified. During the RD, the footprint delineation approach would be applied using updated and expanded data sets and refined models. The approach to footprint delineation is described in Appendix H.

3.1.1 Key Question

The key question that addresses this hypothesis is:

Does the IR footprint adequately capture sediment sources?

This question tests Hypothesis 1.1 during the PDI, when sampling to delineate the IR footprint would be performed and uncertainty in the delineation would be evaluated. A general time line for adaptive management during IR design and implementation is shown in Figure 3-1. The general decision framework for footprint delineation is presented in Table 2-1, and a decision tree is presented in Figure 3-2.

3.1.2 Uncertainties and Data Needs

The delineation of the IR footprint requires characterization of surficial sediment COC distribution during the PDI to address RAO 1 and a characterization of erosional areas and associated subsurface sediment COC distribution to address RAO 2.

The PDI would include collection of closely spaced (i.e., on 80-ft centers) sediment samples to characterize the surficial sediment contaminant distribution. These data would be used to develop a continuous map of surficial sediment bed concentrations using geostatistical interpolation (see Appendix H). Uncertainty in the mapped concentrations would be used to identify areas where additional data are needed, and a second round of sediment sampling would be performed to reduce this uncertainty. The IR footprint would be delineated based on the refined map of surface sediment bed concentrations, and would include areas exceeding the RAL required to achieve the target SWAC, as specified in RAO 1.

The IR footprint would be expanded to include erosional areas with subsurface contaminant concentrations exceeding a subsurface RAL, as specified in RAO 2. Uncertainties in delineating these areas include identification of erosional areas, characterization of the relevant subsurface interval, mapping of the subsurface contaminant concentrations, and specification of the subsurface RAL. The following data would be used to address these uncertainties:

- Current Conditions Sampling: Bathymetry surveys performed as part of the current conditions sampling would be used together with bathymetry collected during the RI (and the PDI) to characterize erosion and deposition areas, the relevant subsurface interval for RAO 2. These data would also be used to refine the numerical models. The evaluations of bathymetry would be performed during the RD.
- PDI: The sediment data collected during the PDI would be used to characterize and map contaminant concentration in the relevant subsurface interval for RAO 2 during the RD.

3.1.3 Adaptive Responses

Adaptive responses to new information collected during the current conditions sampling and the PDI include:

- Development of an additional, focused sediment sampling program to reduce uncertainty in the remedial footprint during the PDI/RD
- Refinement of numerical models based on the current conditions sampling and/or the PDI
- Use of the refined numerical models during the RD to support identification of erosion and deposition areas in the event that bathymetry data are insufficient (e.g., a high-flow event does not occur during the investigation period to support delineation of erosion areas).

3.2 HYPOTHESIS 1.2: THE IR WILL ADDRESS SEDIMENT SOURCES AND ATTAIN IR RAOs

An IR would be implemented in conformance with project-specific performance criteria to confirm that its construction meets design requirements. BMPs would be implemented to control the impacts of sediment resuspension and contaminant release during construction. Following IR construction, it is assumed that the remedy completion decision would be made within approximately 3 years; this time period would include necessary sampling and data evaluation to assess remedy completion. The successful completion of an IR would be documented by EPA in a certification of Remedial Action Project Completion. A detailed description of the remedy completion process is provided in Appendix H.

3.2.1 Key Question

The key question that addresses this hypothesis is:

Was the IR successfully completed and did it attain the IR FS RAOs upon completion?

This question tests Hypothesis 1.2 during and following implementation of an IR. A successful implementation would mean that the targeted source areas were removed, that resuspension and recontamination during implementation was appropriately managed, and that RAOs were attained upon IR completion. A general time line for adaptive management during IR design and implementation is shown in Figure 3-1. The general decision framework for IR implementation and completion is presented in Table 2-1, and a decision tree is presented in Figure 3-2.

3.2.2 Uncertainties and Data Needs

Uncertainties that would be addressed related to implementation of an IR include effectiveness of construction practices and BMPs to control residuals, completeness of source removal, and achievement of the target post-IR SWACs under RAO 1. The data that would be collected to address these uncertainties include:

- Current Conditions Sampling: The current conditions sampling program provides characterization of pre-IR surface water contaminant concentrations over a range of flow conditions. These data would be used to establish monitoring performance standards to ensure residuals are appropriately managed.
- Construction Performance Monitoring:
  - Water column monitoring and sediment sampling performed during construction would support resuspension and residuals management, where water column concentrations would be compared with performance standards and sediment sampling would evaluate the redistribution of dredge residuals.
  - Bathymetry surveys during construction would be performed to ensure that the target depths are achieved in areas of dredging and that cap/backfill placement was achieved.
- Post-IR Sampling: Sediment sampling would be performed following IR implementation to assess whether the IR achieved the target SWACs established under RAO 1, to assess the possibility of actionable remaining sources should the RAO 1 goals not be attained, and to determine if the IR is complete. More than one round of sediment sampling may be performed to reduce uncertainty in the post-IR SWAC estimates.

3.2.3 Adaptive Responses

During the implementation of an IR, adaptive responses may include modification of construction activities if performance standards are exceeded, if target dredge cuts are not achieved, or if target cap/fill placement is not achieved. While these activities are standard elements of engineering design and implementation of remediation projects, they are included

in this Adaptive Management Implementation Approach, as they may result in changes to planned activities in response to new information.

During the evaluation of remedy completion, collection of additional sediment data may be performed to reduce the uncertainty in the estimated post-IR SWAC. The proposed approaches to calculating SWACs and evaluating uncertainty are described in Appendix H. If the remedy completion evaluation indicates that the IR was not completed successfully, data would be evaluated for the presence of additional sources, and the need for additional actions considered, as described in Appendix H.

4 ADAPTIVE ELEMENT 2: SYSTEM RESPONSE

Following implementation of an IR, it is expected that recovery trajectories of tissue, water column, and sediment would be accelerated relative to pre-IR, and that the enhanced understanding of the system would support reliable model projections of future recovery. The current understanding of the physical, chemical, and biological attributes of the upper 9 miles of the LPRSA is reflected in the current CSM, which was developed based on evaluation of the RI data and the supporting, EPA-approved HST and CFT models.[9]

During the RD phase of an IR, the CSM, empirical data collected during the current conditions program and PDI, and development and application of refined numerical models would provide the basis for setting expectations about the system response to an IR, including the projected sediment recovery trajectory and the associated reductions in tissue concentrations. Within Adaptive Element 2, the observed system response based on empirical data to be collected before, during, and after the implementation of an IR would be evaluated to assess whether key physical and chemical attributes of the system (i.e., the sediment, water column, and tissue) are responding to IR source removal as predicted and to inform updates to the CSM, potential changes to the recovery assessment monitoring program, potential refinement of numerical models, and other decisions related to this adaptive element.

4.1 HYPOTHESIS 2.1: IR SOURCE REMOVAL WILL ACCELERATE OVERALL SYSTEM RECOVERY

Following implementation of an IR, recovery assessment monitoring data would be evaluated to characterize the response of the system to an IR, including determining the post-IR sediment recovery trajectories and evaluating corresponding recovery in tissue and surface water. Observed recovery trajectories would be compared with pre-IR conditions and anticipated recovery of the No Action alternative, based on model projections, to confirm that implementation of an IR has accelerated sediment recovery. These data would also be used to reduce the uncertainties in the relationships between sediment and tissue to support evaluation and selection of final RGs under Adaptive Element 3.

[9] The FWM is under development and would undergo peer review prior to or during the RD phase of the project. It would then be applied during RD to characterize sediment–water–tissue relationships and, based on CFT model projections of water column and sediment concentrations, to project recovery of tissue concentrations in response to an IR. As part of this evaluation, the FWM would be used, along with empirical relationships between sediment and tissue collected during the current conditions sampling program, to establish PRGs (see Adaptive Element 3).

4.1.1 Key Question

The first key decision question of Adaptive Element 2 that would be evaluated following completion of an IR as recovery assessment monitoring data are collected is:

Does the post-IR system demonstrate improved recovery?

This question tests the hypothesis that removing sediment sources will accelerate overall system recovery, as demonstrated by observed recovery trajectories in the empirical recovery assessment monitoring data. A general time line for evaluating the response of the upper 9 miles of the LPRSA through the adaptive management process is shown in Figure 4-1. The general decision framework for adaptive responses based on observed recovery patterns following the implementation of an IR is presented in Table 2-1, and a decision tree is presented Figure 4-2.

4.1.2 Uncertainties and Data Needs

Post-IR recovery trajectories would be established from the recovery assessment monitoring data, which would be collected initially following completion of an IR and regularly thereafter. To confirm that recovery has been accelerated following implementation of an IR, the recovery assessment monitoring data would be compared with the current conditions and PDI data, to characterize changes in sediment, water column, and tissue concentrations resulting from an IR. Observed recovery trajectories would also be compared to model projections for the No Action alternative as a line of evidence to evaluate whether the removal of sources has accelerated recovery.

It is anticipated that, following completion of an IR, the system would require some time (potentially 2 to 3 years or longer) to settle down before a statistically significant trend is discernible. The implementation of the lower 8-mile remediation could also affect observed conditions in the upper 9 miles, and could potentially obscure the ability to discern the recovery trends for some period of time.

The data quality objective (DQO) for data collection to support this hypothesis is to establish post-IR conditions in sediment, the water column, and tissue to support trend evaluation and evaluation of recovery trajectories. The data that would be collected to address this key question are:

- Current Conditions Sampling: Water column and biota data collected prior to implementation of an IR will characterize the baseline tissue and surface water COC concentrations for comparison to post-IR concentrations.
- PDI: Sediment data collected during the PDI provides the pre-IR contaminant concentration in the sediment bed, for comparison to the post-IR concentrations.

- Post-IR Sampling: Sediment data collected at the completion of construction of an IR would provide the post-IR contaminant concentration in the sediment bed, for comparison with the pre-IR concentrations and to quantify the decrease in concentrations resulting from the removal of sources. It is anticipated that these comparisons may be made at varying spatial scales to support diagnostic assessment and evaluation of adaptive responses, if needed.
- Recovery Assessment Monitoring: Sediment, water column, and tissue data collected following completion of an IR would be compared to current conditions, PDI, and post-IR sampling data to assess the response of the upper 9-mile reach to the source removal. This evaluation would include confirmation that recovery has improved by comparison of observed recovery trends with projected recovery trends for a No Action alternative.

4.1.3 Adaptive Responses

Trend analyses would be performed following collection of several years of recovery assessment monitoring data (e.g., 3 to 5 years). If this evaluation does not indicate a discernible trend (i.e., a statistically significant trend not confounded by noise in the data), an assessment would be performed to estimate the anticipated time for trends to emerge, based on the variation observed in the data, and additional data would be collected, followed by a reanalysis of trends. If, following additional data collection, recovery trends are still indiscernible in the data, a diagnostic assessment would be performed to identify why recovery trends are not evident. Potential causes include insufficient data to support trend analysis (temporally or spatially), impacts from the lower 8-mile remedy, or that the CSM did not adequately characterize the system, such that sources were not sufficiently identified.

Possible adaptive outcomes for the diagnostic assessment could include performance of additional years of recovery assessment monitoring to better support the trend analysis and/or modification of the recovery assessment monitoring program in terms of sampling locations and/or sampling frequency of one or more media. Other outcomes could include the need to revisit the CSM and/or the models to identify any system behavior that was not adequately captured (see Section 4.2).

4.2 HYPOTHESIS 2.2: THE CSM AND THE MODEL PROJECTIONS RELIABLY DESCRIBE THE SYSTEM RESPONSE TO THE IR

During the RD phase of an IR, the physical, chemical, and biological data acquired from the current conditions sampling survey and the PDI would be used to refine the existing numerical models, reduce uncertainty in their representation of system conditions, and develop refined projections of system response to an IR, as well as reduce associated uncertainty bounds. Model projections that are not consistent with the observed system response could be indicative

of a gap in the CSM and/or processes that are not well represented in the models. Adaptive refinements to the recovery assessment monitoring program, CSM, and/or models may be warranted during the post-IR recovery of the LPRSA as observed recovery trajectories are compared with model projections. The evaluation of potential supplemental remedial actions that may be necessary based on insufficient system recovery is addressed under Adaptive Element 3.

4.2.1 Key Question

The second key decision question of Adaptive Element 2 that would be evaluated over time as recovery assessment monitoring data are collected is:

Is the system response consistent with the CSM and model projections of recovery?

This question tests the overall hypothesis that the CSM and numerical models represent system behavior and response to an IR with sufficient accuracy and certainty to support overall project objectives, including the evaluation of natural recovery to attain PRGs and, ultimately, RGs (see Adaptive Element 3). A general time line for evaluating the response of the upper 9 miles of the LPRSA through the adaptive management process is shown in Figure 4-1. The general decision framework for adaptive responses based on the consistency of the CSM and numerical models with observed recovery patterns following the implementation of an IR is presented in Table 2-1, and a decision tree is presented in Figure 4-3.

4.2.2 Uncertainties and Data Needs

While the RI provided a data set upon which the current CSM and numerical models are based, the RI data are limited spatially and temporally in the upper 9 miles of the LPR, resulting in significant uncertainty in current understanding of key elements (e.g., current COC concentrations and erosional/depositional behavior). A solid understanding of pre-IR baseline conditions (i.e., hydrodynamics, bathymetry, sediment texture, sediment transport, contaminant fate and transport, and contaminant concentrations in sediment, the water column, and tissue) is necessary for the refinement of physical, chemical, and biological models; development of the recovery assessment monitoring program; and the setting of a basis of comparison for evaluating response of the system to a source control IR. Models, which provide the foundation for understanding sediment transport, contaminant fate and transport, and how receptors are exposed to risk-based COCs, would require refined inputs to ensure they provide usable predictions. The pre-IR baseline condition information, obtained via the ongoing current conditions sampling program and the PDI, would directly support model refinement and calibration and an improved understanding of the exposures to human and ecological receptors. For adaptive management, baseline characterization would directly inform the design of the recovery assessment monitoring program and provide critical data for evaluating overall system response to an IR and assessment of recovery to meet PRGs/RGs in a reasonable time frame (Adaptive Element 3).

The CSM and the EPA-approved numerical models used in the IR FS reflect the current understanding of the LPR system, but the available model projections reflect large uncertainty due to spatially and temporally limited data for model calibration and known limitations of the current model frameworks (e.g., coarse spacing of the HST and CFT model grid). It is anticipated that these models would be updated during the RD, incorporating new information developed in the current conditions sampling program and the PDI to improve the model frameworks. During the RD, the refined models would be used to predict the response of the LPR system, including projected recovery curves for sediment, water, and tissue COC concentrations.

The current conditions and PDI data would be used to refine the HST and CFT models and the FWM. Limitations in the existing HST and CFT model frameworks, data sets that support model parameterization, and model calibration would be addressed in conjunction with the RD to allow for improved model projections.

It is anticipated that model refinement would reduce the uncertainty in the projections and improve their accuracy. During model refinement, an uncertainty evaluation would be performed to define the bounds on the refined projections. The refined models would be applied to support determination of projected recovery curves and develop estimates of time frames needed to attain PRGs/RGs, and model projections would be expressed as ranges to reflect their uncertainty. The application of these models would support the evaluation of overall system response to an IR (Adaptive Element 2) and assessment of recovery to meet PRGs/RGs in a reasonable time frame (Adaptive Element 3).

Data collected throughout the LPRSA following completion of an IR would be used to evaluate system response and its consistency with model projections. The DQO to support evaluation of this hypothesis is to compare post-IR conditions to model projections (updated to reflect post-IR conditions) to support decision-making on the need, if any, for diagnostic assessment of model performance and possible further model refinements, and/or refinement of the recovery assessment monitoring program.

While it is anticipated that the refined models would better represent the long-term system response, the changing conditions resulting from the implementation of an IR could introduce new uncertainty to the model projections. Under Adaptive Element 2, the models would be tested following IR implementation to ensure they are providing useful projections. Recovery assessment monitoring data, including sediment, water column, and tissue COC concentrations and bathymetry surveys, would be used to evaluate model performance and uncertainty. Following several years of recovery assessment monitoring, the data would be compared with model projections. If the recovery assessment monitoring data are largely consistent with model projections over time, this would be evidence that the system is responding to the post-IR conditions as expected and the CSM and the numerical models would be finalized.

However, if the system does not respond as expected, then post-IR refinement of the CSM and numerical models would be considered. For the numerical models, it is anticipated that HST/CFT model boundary conditions (i.e., the hydrograph, upstream loads) and habitat changes that influence the FWM would be routinely updated to reflect observed conditions following IR completion. These limited model updates may be sufficient to demonstrate that recovery is consistent with the CSM and models based on actual system conditions following an IR, allowing the CSM and models to be finalized without further modifications. If the projections remain inconsistent with observed recovery, diagnostic assessment and an adaptive response may be warranted, as described further in Section 4.2.3.

The uncertainties that would be addressed to support the evaluation of overall system response to an IR and associated data needs are discussed in detail below.

4.2.3 Adaptive Responses

If the system responds significantly more slowly than indicated by the model-projected system recovery rates, a diagnostic assessment may be initiated (Figure 4-3). Additional DQOs may be established, and supporting data collection efforts may be undertaken, as part of the diagnostic assessment to evaluate components of the CSM and/or the numerical model that may be called into question by evaluation of the recovery assessment monitoring data. A diagnostic assessment would likely not be necessary if the overall recovery towards the PRGs is progressing adequately.

The general time frame(s) for potential diagnostic assessment and adaptive response is anticipated to be in conjunction with CERCLA 5-year reviews, wherein EPA undertakes a systematic evaluation of remedy performance, or at other times, as warranted by new information and as beneficial to the program. The purpose of the diagnostic assessment would be to identify key factors contributing to observed differences between expected (i.e., model projections) and actual system response to the source removal. The specific activities performed during the diagnostic assessment would be determined based on review of the monitoring data, and may include:

- Focused monitoring to isolate areas of concern
- Increased monitoring frequency to characterize seasonal patterns
- Focused sediment sampling to identify remaining sources not addressed by an IR
- Bathymetric evaluation to assess erosional areas.

Based on the outcomes of the diagnostic assessment, model performance would be reassessed to support a decision on what refinements, if any, to the models are needed to bring their performance into better alignment with the observed response of the system. Model updates may include model recalibration (HST, CFT, and/or FWM) based on observed sediment, water column, and tissue concentrations and bathymetric changes and development of revised model

projections to support reevaluation of anticipated time frames for recovery. If, following any additional data collection and model refinement, the models cannot be brought into satisfactory alignment with the observed data, reliance on the models would be secondary to the role of observed data and empirical recovery trend analysis in the forecasting of future conditions.

5 ADAPTIVE ELEMENT 3: SYSTEM RECOVERY

A recovery assessment would be performed to assess progress towards cleanup goals that are initially defined by the PRGs developed in parallel with the RD phase of the project (Adaptive Element 1). Recovery time frames would be projected at this time using refined projections, acknowledging that model and system uncertainties would still remain. Recovery of the upper 9 miles of the LPRSA would be documented based on data to be collected under the recovery assessment monitoring program (Adaptive Element 2). The design of the recovery assessment monitoring is expected to be derived from the current conditions sampling program results and identification of the key uncertainties identified in establishing initial PRGs. It is expected that the recovery assessment monitoring program would include fish/crab tissue and water column chemistry, as well as periodic sediment chemistry and bathymetry. The monitoring program may be modified through adaptive management, and may be redefined in the final ROD. Primary goals of the recovery assessment monitoring program would be to document system recovery and resolve uncertainties in the PRGs such that final RGs can be established.

5.1 HYPOTHESIS 3.1: RECOVERY ASSESSMENT MONITORING WILL REDUCE UNCERTAINTIES IN THE RELATIONSHIPS BETWEEN SEDIMENT AND TISSUE SO THAT PROTECTIVE SEDIMENT RGs CAN BE ESTABLISHED

Risk-based PRGs are not developed in the IR FS because the goal of an IR for the upper 9 miles of the LPRSA is to address sediment with elevated COC concentrations identified as source areas, and not to achieve explicit risk-based goals.[10] Therefore, the IR FS develops and compares remedial alternatives to control sediment sources. A source control IR would be followed by a period of monitoring and, ultimately, selection of a final remedy for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA. As such, PRGs and ultimately RGs would be developed to identify protective contaminant levels to be achieved by a final remedial action and support EPA's selection of a final remedy, which would be memorialized in a final ROD, as shown on the general adaptive management time line (Figure 2-4).[11]

To support this process, it is anticipated that PRGs for the upper 9 miles of the LPRSA would initially be developed in parallel with the IR RD. The initial PRGs would subsequently be revised, as warranted, based on new information (USEPA 1991a), in conjunction with CERCLA

[10] Insufficient information is available at this time to develop PRGs; however, PRGs will be developed after the FWM is finalized and peer reviewed.
[11] PRGs are not actionable requirements for establishing the scope of a final remedial action or determining remedial action completion. Actionable RGs would be established in a final ROD for the LPRSA.

5-year remedy reviews, or as warranted by new findings. Refinement of the PRGs would draw on relevant new data and information that may become available during IR implementation and monitoring to reduce uncertainty in the inputs to the PRGs, consistent with the Region 2 response to CSTAG's second IR review (USEPA 2020b). This approach is consistent with adaptive management principles and EPA guidance that recognizes that PRGs may be progressively refined during the RI/FS process and prior to establishing final RGs in the final ROD (USEPA 1999).

PRGs and RGs would be developed for COCs identified as human health and/or ecological risk drivers in the EPA-approved LPRSA baseline risk assessments (AECOM 2017; Windward 2019a). Table 5-1 summarizes the human and ecological receptors and exposure pathways that present unacceptable risk from the associated risk drivers, and the environmental media to be evaluated in the development of PRGs and RGs.

5.1.1 Key Question

The key question that addresses this hypothesis is:

> *Is information available that suggests uncertainty in PRG inputs can be further constrained and that refinement of PRGs is warranted?*

PRGs and RGs identify contaminant concentrations or risk levels in environmental media (e.g., sediment, water, or tissue) that protect human health and/or the environment for a given exposure scenario and comply with applicable or relevant and appropriate requirements (ARARs) (USEPA 1991b,c; 1997; 1999). EPA guidance anticipates that the process of developing PRGs may be iterative, in that PRGs may be refined over time as better site-specific information becomes available, culminating in the identification of RGs in a final ROD that establishes final remediation requirements for a site.

This question provides a mechanism for testing the hypothesis that uncertainty in the PRG inputs is constrained to the extent feasible, such that RGs can be established and an appropriate final remedy selected. That is, available data and information have been collected and applied to address uncertainty in the PRG inputs to the point at which no additional reduction in this uncertainty can be reasonably attained (e.g., additional data collection would not be expected to substantially reduce the remaining uncertainty).

The adaptive approach to addressing this question is illustrated conceptually in Figure 5-1, relating the major project activities and milestones to the development of PRGs and RGs.

PRGs would initially be developed concurrently with the RD based on the EPA-approved human health risk assessment and baseline ecological risk assessment (AECOM 2017;

Windward 2019a), historical and current conditions data, CFT model projections, and the peer-reviewed FWM. The uncertainty in the initial PRGs would be characterized to highlight where opportunities may exist to reduce uncertainty and improve the derivation of protective PRGs. Key variables that influence the derivation of the initial PRGs would be identified, and the sensitivity of the PRGs to the uncertainty in these variables would be evaluated. This information would be used to prioritize data collection and other efforts during IR implementation and recovery assessment monitoring. This approach emphasizes activities that would have the greatest effect on reducing uncertainty in the PRGs to support selection of the final RGs, thereby providing assurance that the final remedy would be protective. Refinement of the PRGs, if warranted, in response to new information would likely occur in conjunction with the CERCLA 5-year review process for the LPRSA, or at other times, as warranted by new information and as beneficial to the program. Final RGs would be established in a final ROD.

General time lines for PRG/RG development and refinement during system recovery are shown in Figure 5-2a (recovery progressing acceptably) and Figure 5-2b (recovery not progressing acceptably). The general decision framework for the potential refinement of PRGs and, ultimately, determination of RGs in the final ROD is presented in Table 2-1, and a decision tree is presented in Figure 5-3. The time line, decision framework, and decision tree present the adaptive management process for using site information to constrain uncertainty in the PRGs and RGs to the extent feasible.

5.1.2 Uncertainty and Data Needs

Development of sediment PRGs/RGs relies on several types of data, information, and models. These include sediment, surface water, and tissue COC data, projections of surface water and sediment concentrations from the CFT model, parameterization and calibration of the FWM, characterization of the food web structure, site-specific exposure information and assumptions, and COC toxicity information derived from the scientific literature and EPA guidance. Key input parameters and data uncertainties for PRG development are identified in Table 5-2. Some of these variables have substantial uncertainties that may be reduced through additional data to be collected during the ongoing current conditions sampling program, the PDI, and recovery assessment monitoring. In particular, recognizing that the relationships between biota and sediment concentrations may be influenced by IR implementation, the recovery assessment monitoring is expected to provide an improved understanding of these relationships following the removal of sediment with the highest concentrations of COCs. Therefore, factors driving the uncertainty of the PRGs would be elucidated when they are initially developed concurrently with the IR RD to provide a basis for future refinement. Following calibration and peer review of the FWM and development of the initial PRGs, if uncertainties are identified that can improve and refine the initial PRGs, then additional data collection would be conducted to reduce or resolve these uncertainties.

In this appendix, it is assumed that the initial PRGs for sediment would be derived based on COC tissue concentrations that are expected to be protective for the fish consumption pathway, application of the CFT model and the FWM, and empirical data collected during the RI, current conditions sampling, and the PDI. Because the derivation of initial PRGs would rely solely on pre-IR information, models, and assumptions, the relationship between sediment and tissue is expected to remain one of considerable uncertainty at this stage.

Recovery assessment monitoring would provide data that are anticipated to improve the scientific understanding of the overall system response and natural recovery processes following an IR (see Adaptive Element 2), support the potential development of better estimates of sediment and water column COC concentrations via the CFT model and uncertain FWM variables, and yield improved insight into the interactions among concentrations of COCs in sediment, the water column, and tissue. These outcomes may provide opportunities to refine the initial PRGs as recovery assessment monitoring proceeds, prior to determining final RGs in a final ROD. As shown in Figures 5-2a and 5-2b, such opportunities would likely be evaluated in conjunction with CERCLA 5-year reviews for the LPRSA, or at other times, as warranted by new information and as beneficial to the program.

As recovery assessment monitoring progresses, more information regarding the relationships between sediment, water column, and tissue data would be collected. Based on these new data and the evaluation of recovery relative to the PRGs, the PRGs may be refined at one or more points before RGs are specified in a subsequent, final ROD. It is also anticipated that EPA may establish interim risk-based thresholds for fish and crab tissue concentrations and/or guidance on fish meal consumption to communicate risk reduction expectations and progress to stakeholders over the course of the long-term recovery assessment.

It is anticipated that the final ROD for the LPRSA would establish RGs for sediment in the upper 9 miles and for surface water throughout the LPRSA. For surface water, although the implementation of sediment remedial actions is expected to contribute to improvements in surface water quality in the LPR over the long term, attainment of the New Jersey surface water quality standards (SWQS), a probable ARAR for the final ROD, solely through remedial actions on sediment in the LPRSA may be technically impracticable due to regional background surface water concentrations (i.e., above Dundee Dam) that may exceed the New Jersey SWQS for several COCs including 2,3,7,8-TCDD, 4,4′-DDE, 4,4′-DDT, and total PCBs—based on the results of background surface water sampling performed during the RI (Table 5-3). Flows from upstream of Dundee Dam account for more than 80 percent of the freshwater inflow into the LPRSA; these waters mix with tributary inflows and tidal flows exchanged with Newark Bay. Due to these factors, a technical impracticability waiver (TI waiver) for the New Jersey SWQS is expected to be required for any final remedial action in the LPRSA. A TI waiver may be granted when remedial actions at a site cannot achieve ARARs, which include the New Jersey SWQS.

5.1.3 Adaptive Responses

PRGs may be updated as an improved understanding of the key factors that influence their determination and define their uncertainty is obtained from IR implementation and recovery assessment monitoring. New data and other information collected as part of the recovery assessment monitoring program would be evaluated for their ability to constrain the uncertainty in the PRG inputs. As shown in the PRG/RG development decision tree (Figure 5-3), the following potential outcomes may inform the potential refinement of the PRGs and the selection of final RGs for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA:

- If new data and/or other new information are generated during recovery assessment monitoring that allow the uncertainty in PRG inputs to be reduced, the PRGs would be refined and used in the assessment of recovery.
- If the new data and/or other new information do not reduce uncertainty in the PRG inputs, the existing PRGs would continue to be used in the assessment of recovery.

Recovery assessment monitoring would continue until the issuance of a final ROD that identifies a final remedy for sediment in the upper 9 miles and for surface water throughout the 17-mile LPRSA, including associated long-term monitoring requirements. Final RGs would be established in the final ROD and would reflect the refinement of key factors influencing RGs as well as a final evaluation of the CSM and model outputs.

5.2 HYPOTHESIS 3.2: RISK-PROTECTIVE LEVELS WILL BE ATTAINED IN A REASONABLE TIME FRAME

The recovery assessment monitoring data would be documented and evaluated on an ongoing basis following an IR, which would support a comprehensive evaluation of the trajectory of recovery toward the attainment of risk-protective levels to be performed as part of each CERCLA 5-year review (Figure 5-4), or at other times, as warranted by new information and as beneficial to the program. The anticipated year-to-year variability of tissue and water quality data would likely preclude a confident assessment of recovery performance within the first few years following completion of an IR (see Section 4.1), and assessment of recovery rates would be performed as data become available to support the evaluation.

This Adaptive Management Implementation Approach is generally focused on decision-making following an IR and leading to the final ROD, and will be revised in the future, as discussed in Section 1.3, to include a more detailed integration of the ultimate attainment of risk-protective conditions as a discrete component of adaptive management. This revision is anticipated to include hypotheses, decision questions, and a discussion of uncertainties, data needs, decision

points, potential outcomes, diagnostic assessments, and adaptive responses focused on attainment of risk-protective levels through implementation of the final ROD. It is anticipated that this revision will be performed in parallel with the development of the final ROD.

5.2.1 Key Question

The key decision question related to recovery time frames that would be asked over time as recovery assessment monitoring data are collected is:

Can risk-protective conditions be attained in a reasonable time frame?

This question tests the overall hypothesis that the recovery of COC concentrations following the completion of an IR would result in the attainment of protective levels in a reasonable time frame. Expectations for what would be considered a reasonable time frame for attaining protective levels and corresponding estimates of recovery rates for comparison with recovery assessment monitoring results would initially be established during RD, based on refined model projections, the initial PRGs, and as approved by EPA in consultation with other project stakeholders. Following IR implementation and collection of several years of recovery assessment monitoring data, the time frame may be reevaluated and potentially revised to reflect the observed rates of recovery and the refinement of PRGs.

A time line for evaluating recovery to attain PRGs/RGs through the adaptive management process is shown in Figure 5-2a; in this figure, it is assumed that recovery is progressing acceptably. A second time line, assuming that recovery is not progressing acceptably, is presented in Figure 5-2b. In the latter case, additional time and additional assessment of recovery would be necessary to allow for a diagnostic assessment and potential additional actions, if determined to be necessary. The general decision framework for adaptive responses (e.g., determining if the recovery rate is progressing in a reasonable time frame, consideration of potential additional action) is presented in Table 2-1, and a decision tree is presented in Figure 5-4.

5.2.2 Uncertainty and Data Needs

The DQOs for data collection to support the recovery assessment are:

1. Establish post-IR conditions to support recovery trend evaluation.
2. Evaluate post-IR COC recovery trajectories in sediment, surface water, and tissue to support decisions regarding whether recovery is progressing toward the attainment of PRGs/RGs within a reasonable time frame.

3. Compare post-IR conditions to PRGs to support decision-making on the need, if any, for (a) diagnostic assessment of factors that may be inhibiting system recovery, (b) refinement or recalibration of the models to support PRG refinement and/or establishing final RGs, (c) consideration of additional active remedial measures that may be needed under a final ROD to achieve RGs in a reasonable time frame, and (d) assessment of actual recovery to RGs and attainment of RGs (as part of a final remedy, as implemented).

The ability of monitored natural recovery (MNR) to achieve PRGs and, ultimately, final RGs following the implementation of a source control IR would be a major factor in determining whether the final ROD would identify MNR as the final remedy for the LPRSA or if additional action would be required to reach protective, risk-based RGs. It is anticipated that the final ROD would include a component of MNR, regardless of whether additional active remediation is also undertaken as part of the final remedy. A long-term monitoring program, which may or may not be the same as the recovery assessment monitoring program implemented following performance of the IR, would be developed in the final ROD. The duration of monitoring that may be needed to establish attainment of the RGs is uncertain at this time and would be evaluated during final remedy evaluation and selection. An EPA determination of Construction Completion indicating that no further action is required to meet all CERCLA requirements for the LPRSA would follow the attainment of the RGs. Accordingly, the time frame for this determination is also uncertain.

Much of the data generated by the recovery assessment monitoring program described above in Section 2.4.4 would be the basis for assessing recovery to attain PRGs and, ultimately, RGs. This assessment would rely on sediment, water column, and tissue data collected during recovery assessment monitoring as the primary basis for tracking recovery performance. The data would be analyzed for trends and compared to the PRGs to assess recovery and anticipated time frames for achieving goals. Comparison of recovery trajectories to the PRGs would inform decision-making about potential requirements for a final remedy.

The data would also be used diagnostically in the recovery assessment as a basis for evaluating and identifying causal factors if recovery is not progressing at an acceptable rate to reach risk-protective PRGs/RGs in a reasonable time frame.

Data evaluations undertaken as part of this adaptive element may include statistical and graphical representations including comparisons to projected ranges of recovery rates and time frames. Statistical evaluations would generally be given greater weight than graphical methods, as the former provide quantitative, as opposed to visual, tools for detecting and analyzing data trends. Data exploration tools would be used first to identify appropriate tests, and additional methods may be employed, as necessary, as the data are further assessed. Data evaluation method selection would consider the following factors:

1. Recovery is not expected to be monotonic over time due to anticipated interannual variability and episodic high flow events that may be observed in recovery assessment monitoring data, which may significantly obscure trends
2. Recovery rates may vary by sample medium and fish species and crabs
3. Recovery rates may vary by COC
4. Recovery rates may vary spatially by river reach.

Data and model projections would directly inform the assessment of recovery. Model projections would establish a range of anticipated time frames for recovery, with the ranges to be developed based on an uncertainty analysis of the model projections. Observed tissue concentrations would be compared with ranges of species-specific FWM recovery projections to assess whether the data are within the bounds of the projections. (Models may be assigned a secondary role in this evaluation if they cannot be brought into good alignment with empirical observations through reasonable efforts that may be undertaken under Adaptive Element 2.) Outcomes of the recovery assessment include:

- If recovery is consistent with projections and progressing toward PRGs/RGs in a reasonable time frame, then information to support a final ROD would be prepared, including establishing RGs, selecting MNR as the final remedy, and defining the long-term monitoring program that would provide data to support EPA issuing a no-further-action determination.
- If a comparison of tissue data and FWM projections is uncertain (e.g., there is large interannual variation in tissue concentrations that obscures trends), monitoring would continue and recovery would be reassessed. In addition, a diagnostic assessment may be initiated to identify causal factors or model limitations that contribute to uncertainty in the comparison.
- If evaluation of recovery is not progressing as expected, a diagnostic assessment would be performed, as discussed below.

5.2.3 Adaptive Responses

As shown in the recovery assessment decision tree (Figure 5-4), if the recovery assessment monitoring data indicate recovery is not progressing adequately toward protective levels as defined by the PRGs in a reasonable time frame, then a diagnostic assessment would be triggered to understand overall differences in recovery patterns (which may vary by medium, location, species, and/or age class) and the causal factors that may be inhibiting recovery. Further evaluations of existing data (e.g., more detailed statistical and/or geostatistical analyses; consideration of potential geographic and climatic influences on spatial and temporal data variability, evaluations at differing spatial scales) may be undertaken as a first step in the

diagnostic assessment to determine whether such causal factors are identifiable. If causal factors cannot be identified, additional data collection may be initiated to isolate them. The specific data collection activities that could be performed during the diagnostic assessment could include:

- Focused biota and/or water column monitoring to isolate species and/or areas of concern
- Increased biota monitoring frequency to characterize seasonal patterns
- Focused sediment sampling and/or bathymetry surveys to identify potential unknown source areas (including, for example, identification of previously unknown upland sources or subsurface sediment sources that may become exposed due to erosion in unforeseen areas).

Once the factors that are inhibiting recovery are known, the models and PRGs may be refined (if warranted), which may provide a better understanding of the time needed for recovery in the absence of additional action. A decision point would be reached at the culmination of the diagnostic assessment on the potential need for additional action to improve recovery and/or continuation of long-term monitoring. It is assumed that any additional action needed to achieve acceptable recovery would be memorialized in a final ROD for the LPRSA.

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Figures

LPRSA Upper 9-Mile Adaptive Management Plan

Adaptive Management Objective:
Identify information and actions required to promote and attain the overall protection of human health and the environment, initially for the upper 9 miles of the LPRSA and subsequently the entire LPRSA

ADAPTIVE ELEMENT 1:
IR Design and Implementation

Hypothesis:

#1: Sediment sources that inhibit system recovery can be identified.

#2: The IR will address sediment sources and attain interim remedy RAOs.

Decision Questions:

#1: Does delineation of the IR FS footprint adequately capture sediment sources?

#2: Was the IR successfully completed and did it attain the IR FS RAOs upon completion?

ADAPTIVE ELEMENT 2:
System Response

Hypothesis:

#1: IR source removal will accelerate overall system recovery.

#2: The CSM and the model projections reliably describe the system response to the IR.

Decision Questions:

#1: Does the post-IR system demonstrate improved recovery?

#2: Is the system response consistent with the CSM and model projections of recovery?

ADAPTIVE ELEMENT 3:
System Recovery

Hypothesis:

#1: Recovery assessment monitoring will reduce uncertainties in the relationships between sediment and tissue so that protective sediment RGs can be established.

#2: Risk-protective levels will be attained in a reasonable time frame.

Decision Questions:

#1: Is information available that suggests uncertainty in PRG inputs can be further constrained and that refinement of PRGs is warranted?

#2: Can risk-protective conditions be attained in a reasonable time frame?

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Figure 2-1.
Adaptive Management Elements for the Upper 9 Miles of the LPRSA

Key Uncertainties	Project Phase	Adaptive Management Elements: ELEMENT #1 IR Design and Implementation	ELEMENT #2 System Response	ELEMENT #3 System Recovery
	Current Conditions Monitoring, PDI, and Remedial Design	• Pre-IR Conditions • SWACs • Spatial Distribution of Sources • Erosion/Deposition Areas • Model Frameworks/Calibration • Constructability		• PRGs
	IR Implementation and Completion	• Effectiveness of BMPs • IR RAO Attainment • IR Completion	• Post-IR Conditions • Impact of Lower 8 Remedy	
	Post-IR Recovery Assessment		• Long-term Conditions (including erosion/ deposition) • System Response to IR • System Recovery • Model Reliability • CSM Validity	• PRGs
	Development and Implementation of Final ROD			• PRGs • RGs • System Recovery • Reasonable Time Frame • Sufficiency of MNR • Constructability • Technical Impracticability • Construction Completion • NFA

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Figure 2-2.
Relationships between Key LPRSA Uncertainties and the Adaptive Management Elements

Stakeholder	Role
EPA Region 2	• Lead agency • Remedy selection and oversight
NJDEP	• Support agency • Consultation with Region 2 • State acceptance
Federal Trustees	• General review and feedback on response actions • Oversight of resource protection
Performing Parties	• IR design • IR implementation and completion • Recovery assessment monitoring • Adaptive management actions
Local Governments	• Public comment (community acceptance)
Community	• Public comment (community acceptance)

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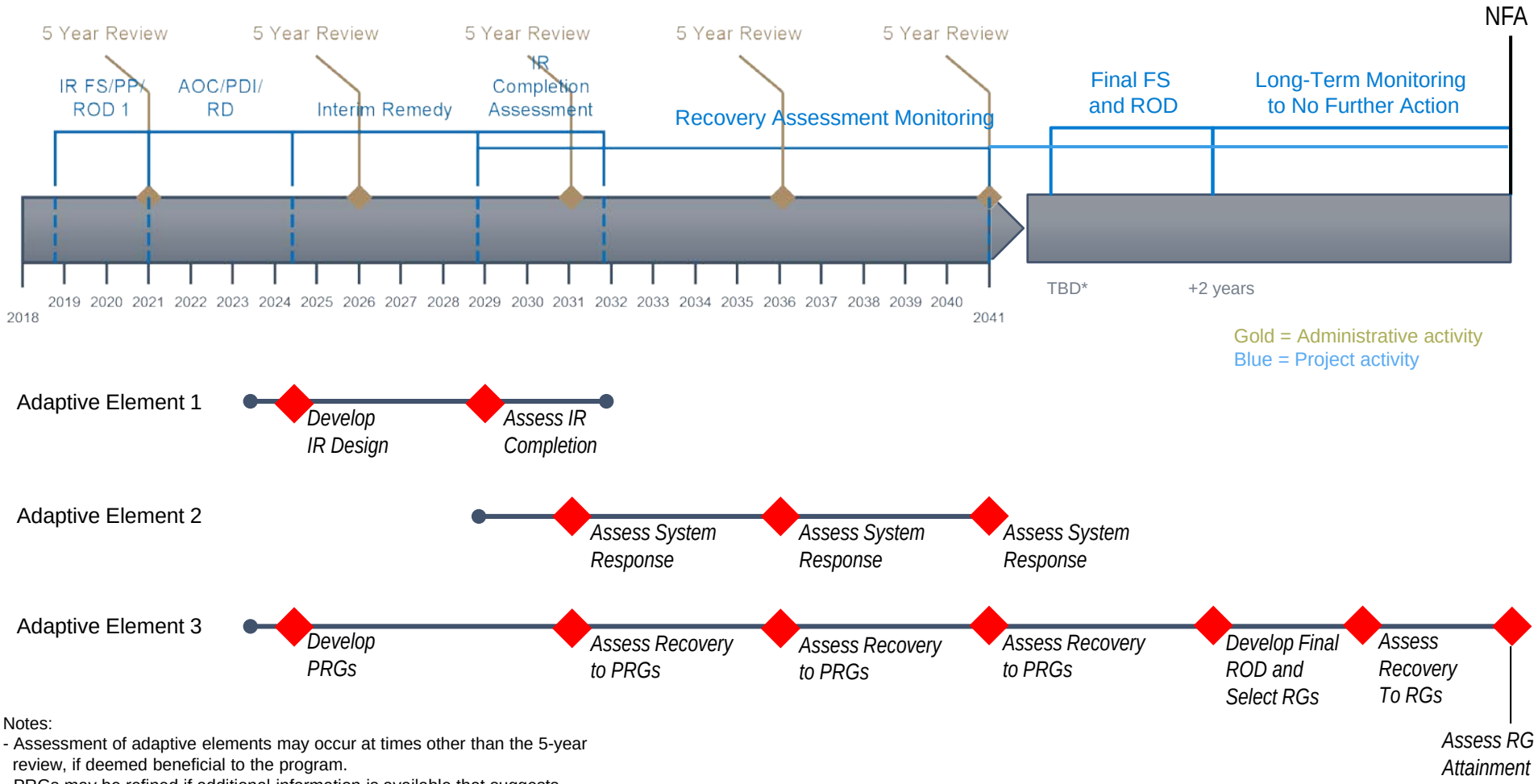
Figure 2-3.
Stakeholders and Roles for Adaptive Management of the LPRSA Upper 9 Miles



Notes:
- Assessment of adaptive elements may occur at times other than the 5-year review, if deemed beneficial to the program.
- PRGs may be refined if additional information is available that suggests uncertainty can be further constrained for particular PRG inputs and that refinement of PRGs is warranted.
- The time frame for a final FS and ROD would depend on decision time frames for Adaptive Element 3 and the need for possible follow-on actions.

Decision Point. See Sections 3 through 5 and associated decision trees for potential response actions.

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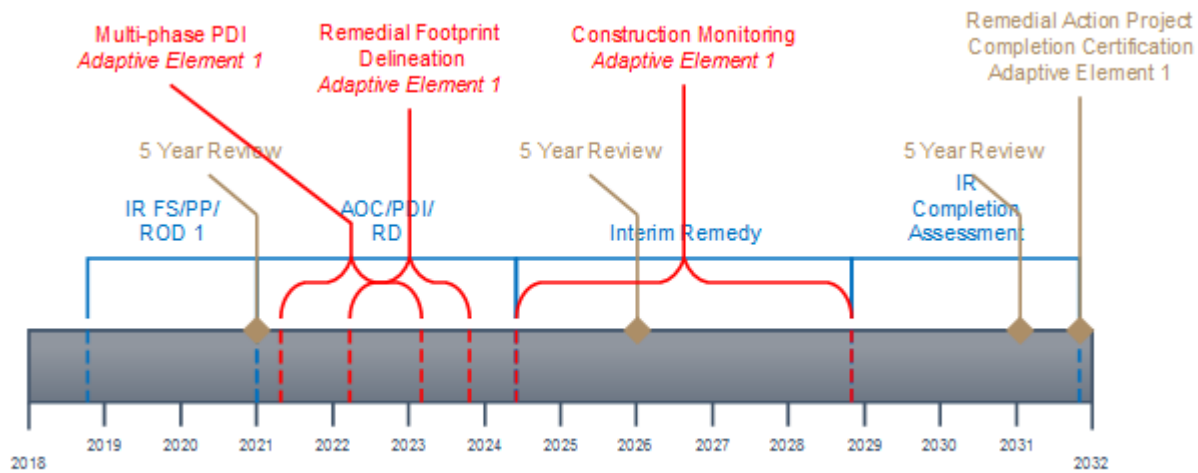
Figure 2-4.
General Time Line for LPRSA Upper 9-Mile Interim Remedy Adaptive Management



Gold = Administrative activity
Blue = Project activity
Red = Adaptive management activity

The IR Completion Assessment includes statistical evaluation of the post-IR confirmation sediment data to assess attainment of RAO 1, assessment of potential actionable remaining sources, and evaluation of the potential for further action under the IR to address actionable remaining sources as adaptive management activities.

Assessment of adaptive elements may occur at times other than the 5-year review, if deemed beneficial to the program.

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Figure 3-1.
Time Line for IR Design and Implementation

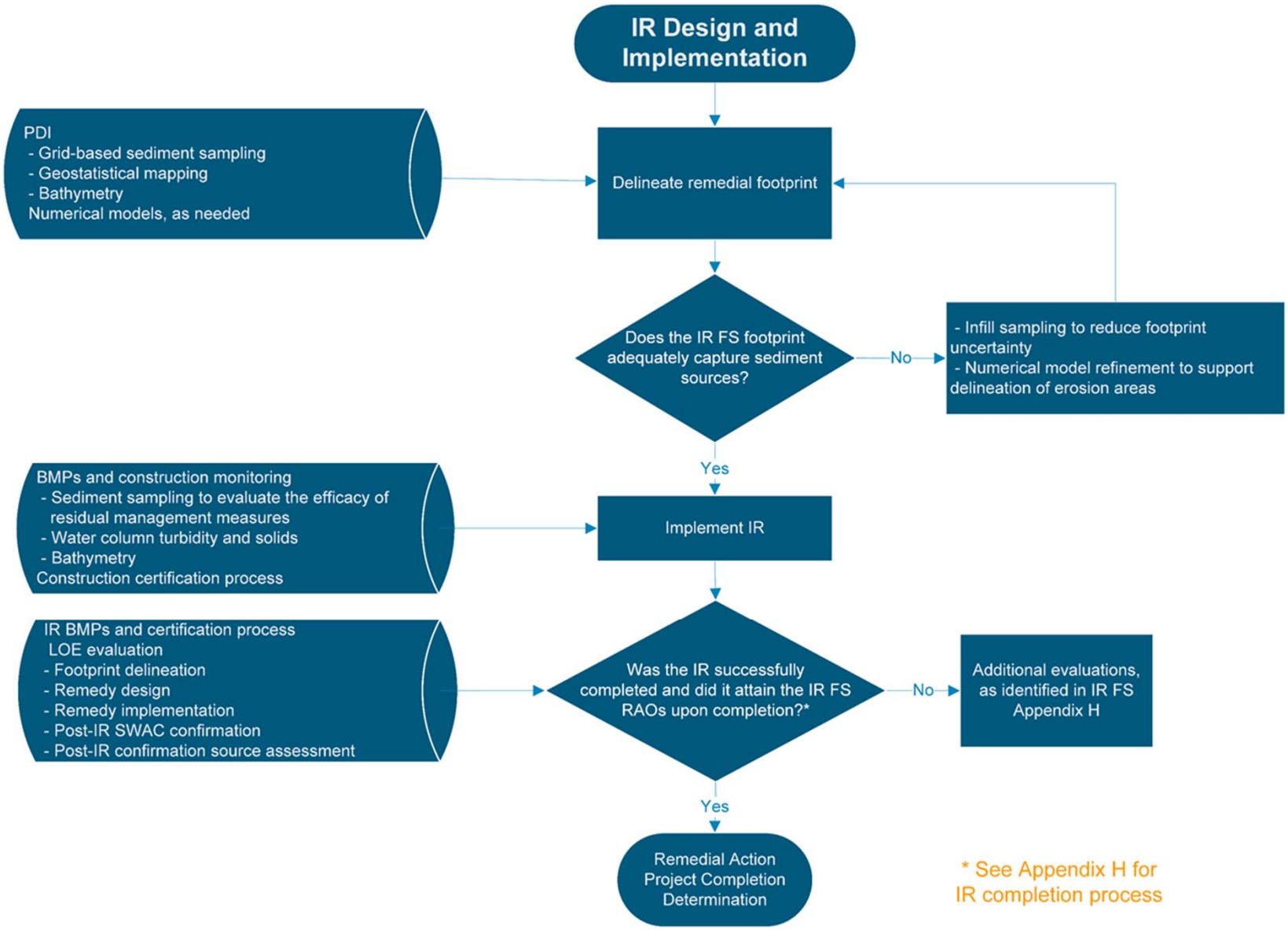
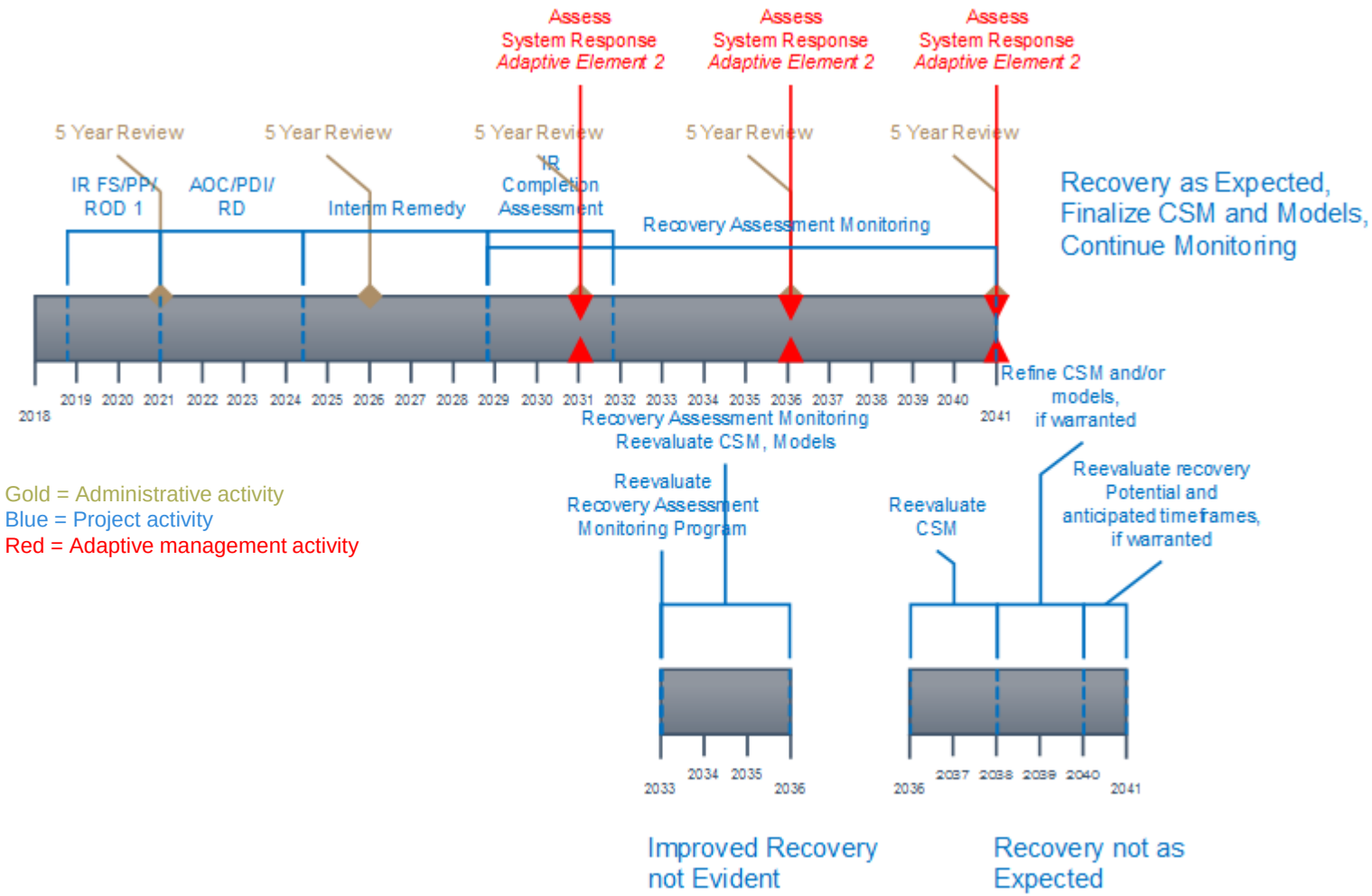


Figure 3-2.
Decision Tree: IR Design and Implementation



Assessment of adaptive elements may occur at times other than the 5-year review, if deemed beneficial to the program.

Figure 4-1.
Time Line for Overall System Response

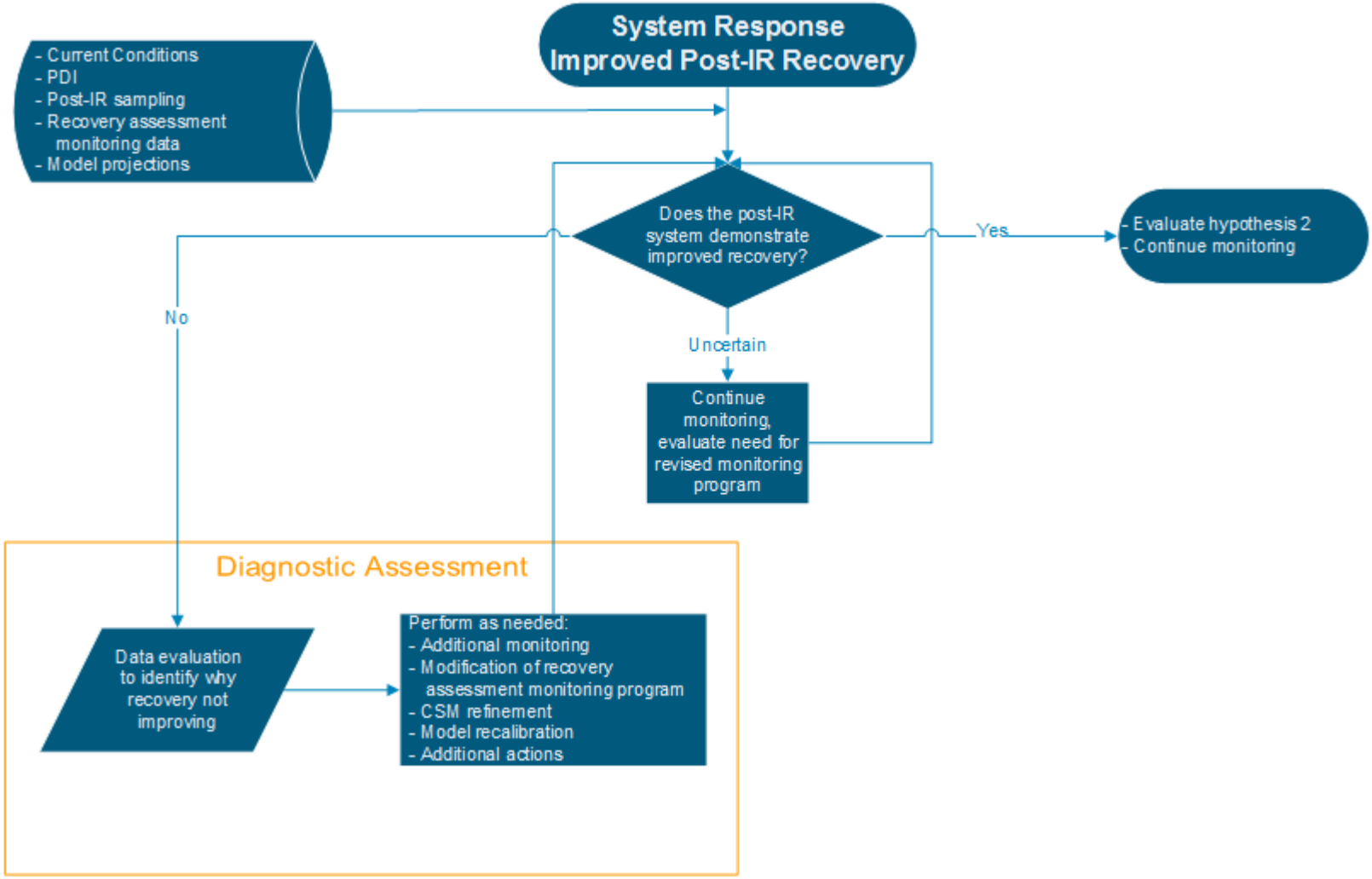


Figure 4-2.
Decision Tree: System Response—Post-IR Recovery

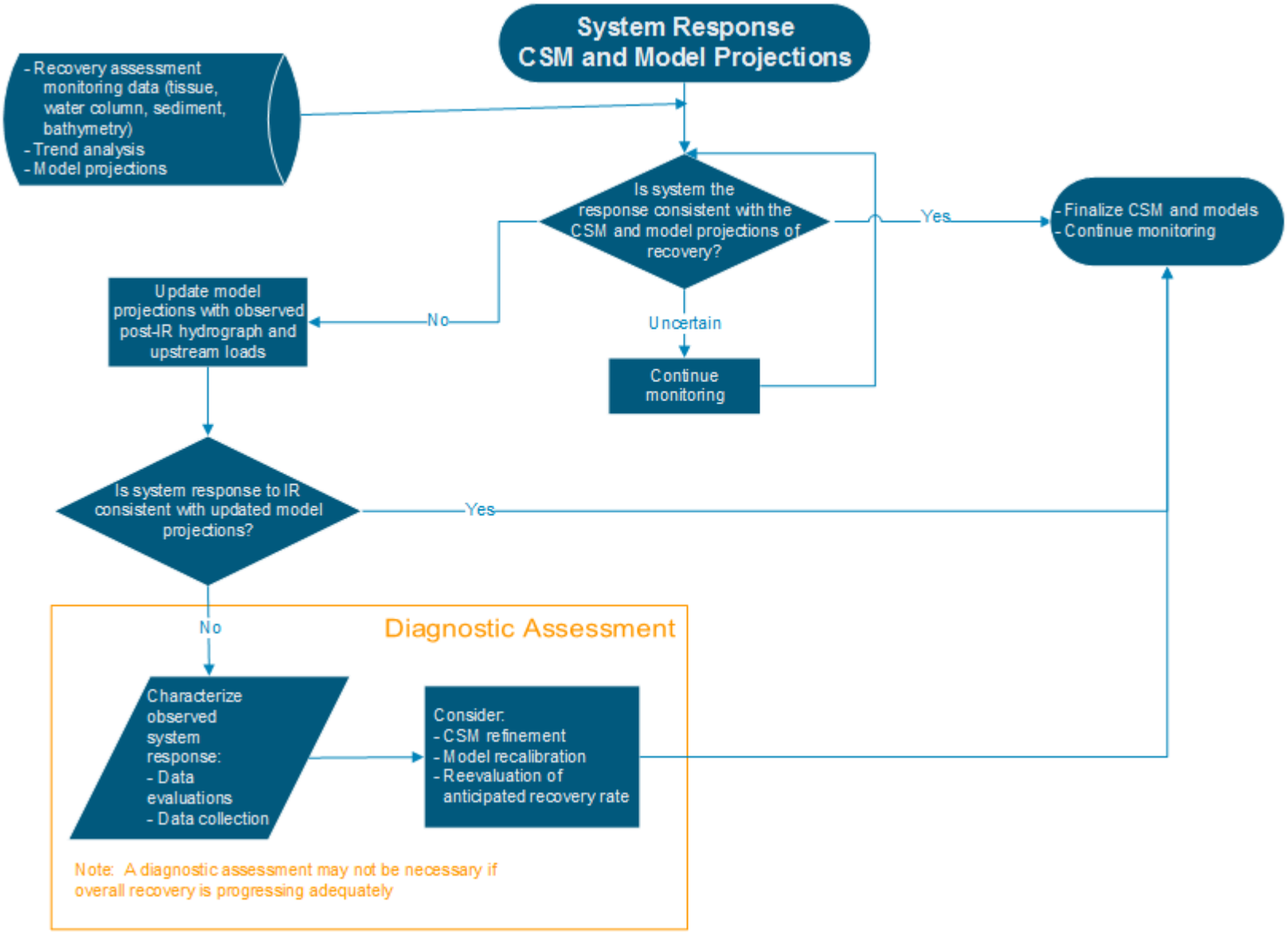


Figure 4-3.
Decision Tree: System Response—CSM and Model Projections

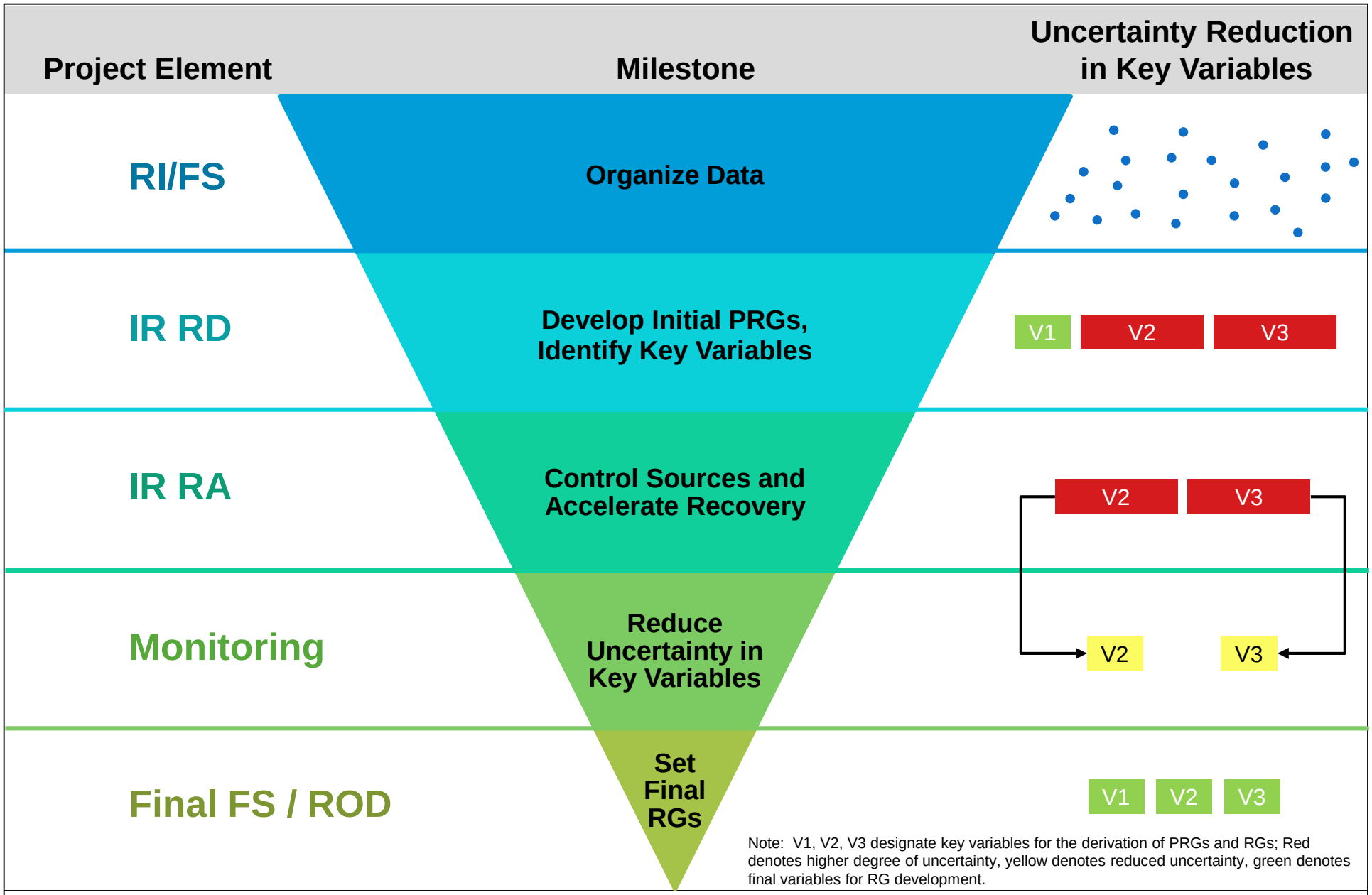


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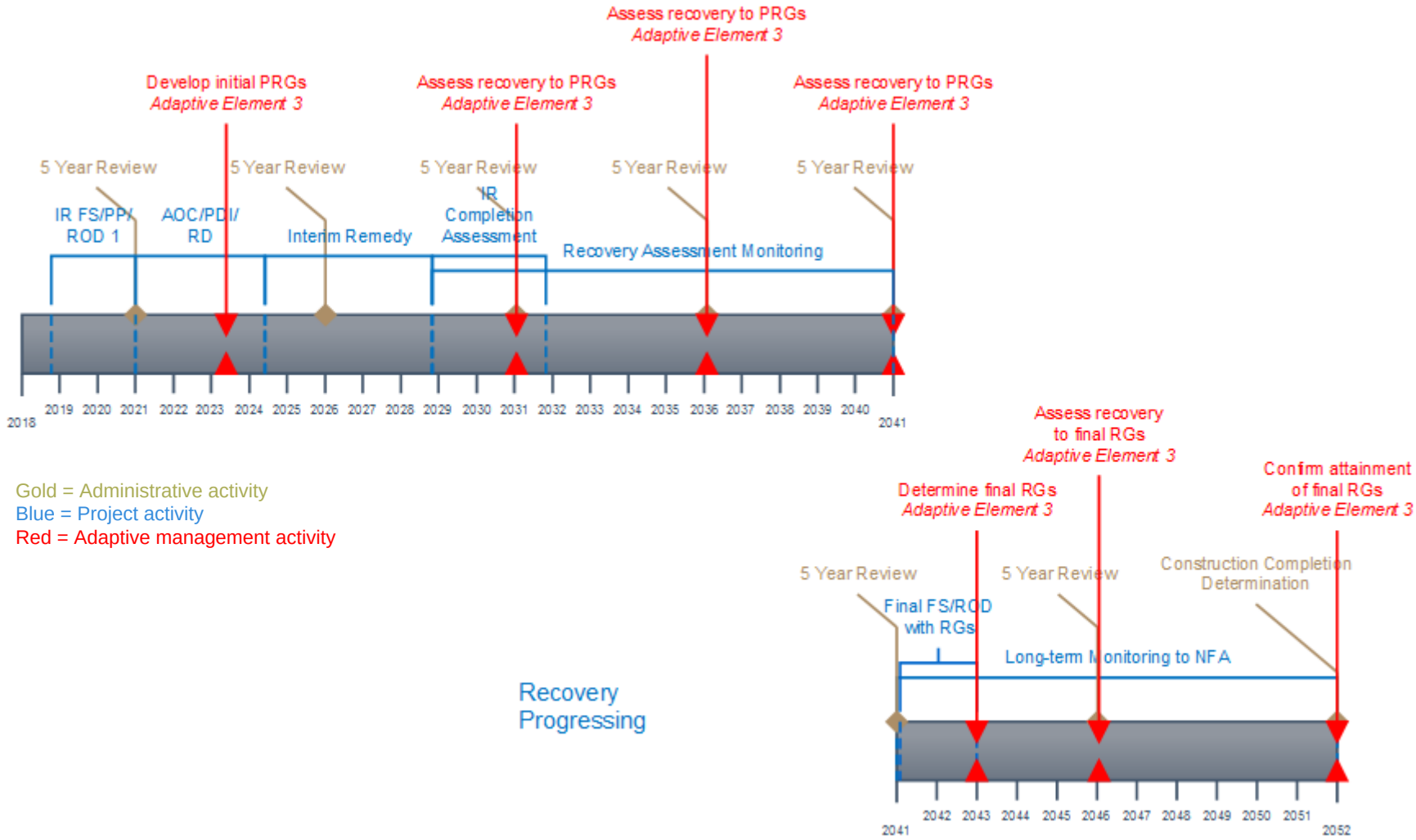
Figure 5-1.
PRG and RG Refinement Process



Notes:
- Assessment of adaptive elements may occur at times other than the 5-year review, if deemed beneficial to the program.
- PRGs may be refined if additional information is available that suggests uncertainty can be further constrained for particular PRG inputs and that refinement of PRGs is warranted.

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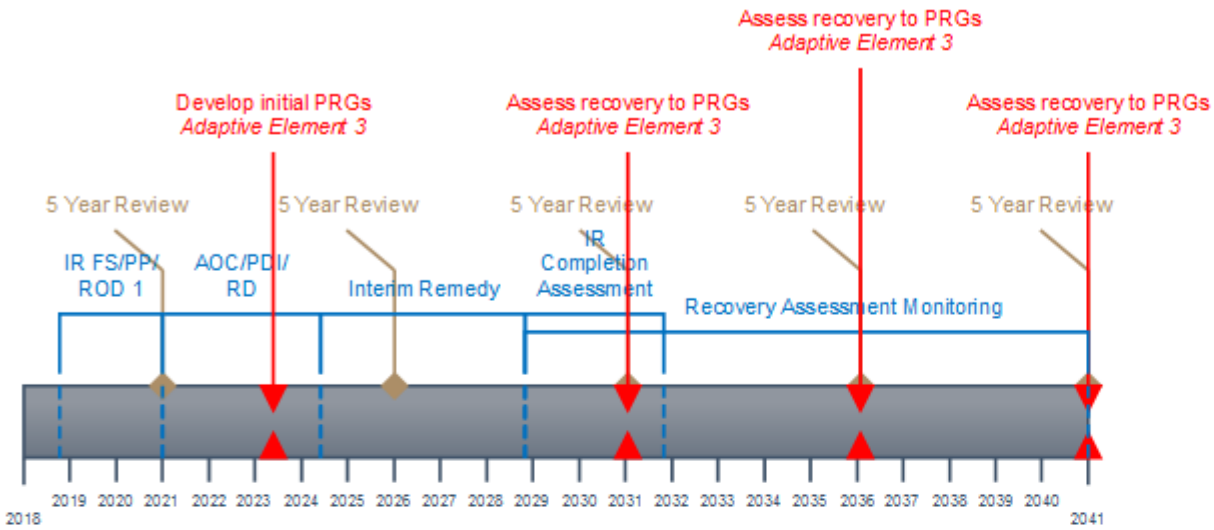
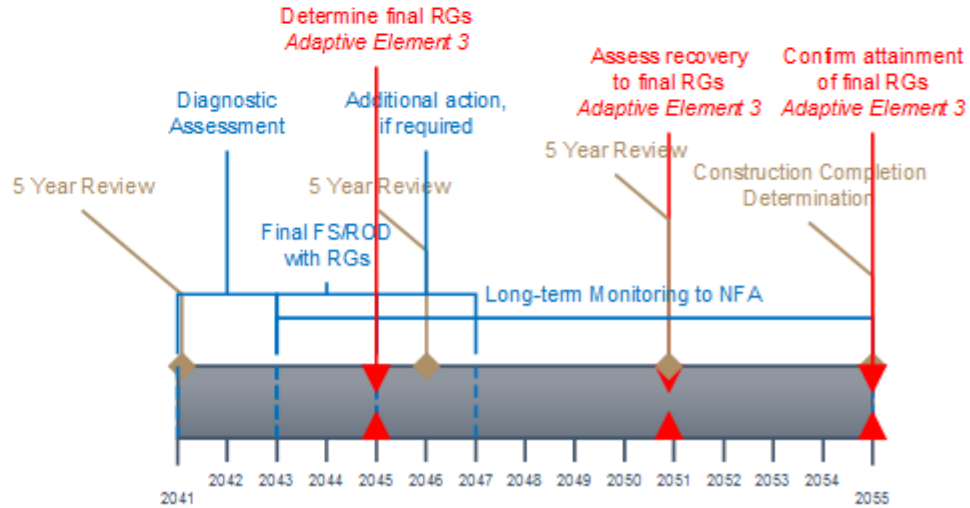
Figure 5-2a.
Time Line for Adaptive Management of System Recovery—Recovery Progressing



Gold = Administrative activity
Blue = Project activity
Red = Adaptive management activity

Recovery Not Progressing



Notes:
- Assessment of adaptive elements may occur at times other than the 5-year review, if deemed beneficial to the program.
- PRGs may be refined if additional information is available that suggests uncertainty can be further constrained for particular PRG inputs and that refinement of PRGs is warranted.

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Figure 5-2b.
Time Line for Adaptive Management of System Recovery—Recovery Not Progressing

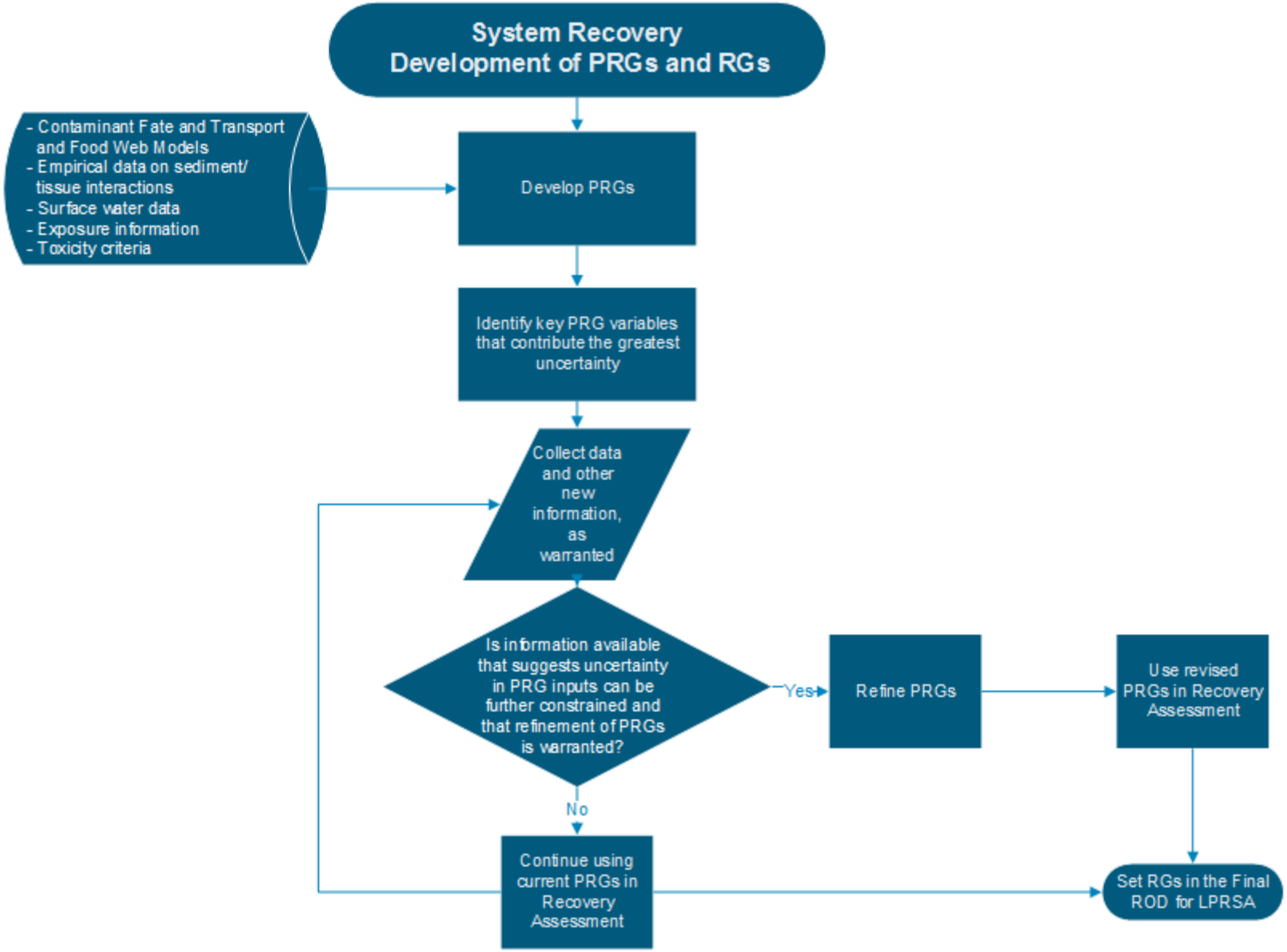

Figure 5-3.
Decision Tree: System Recovery—Development and Adaptive Refinement of PRGs and Final RGs

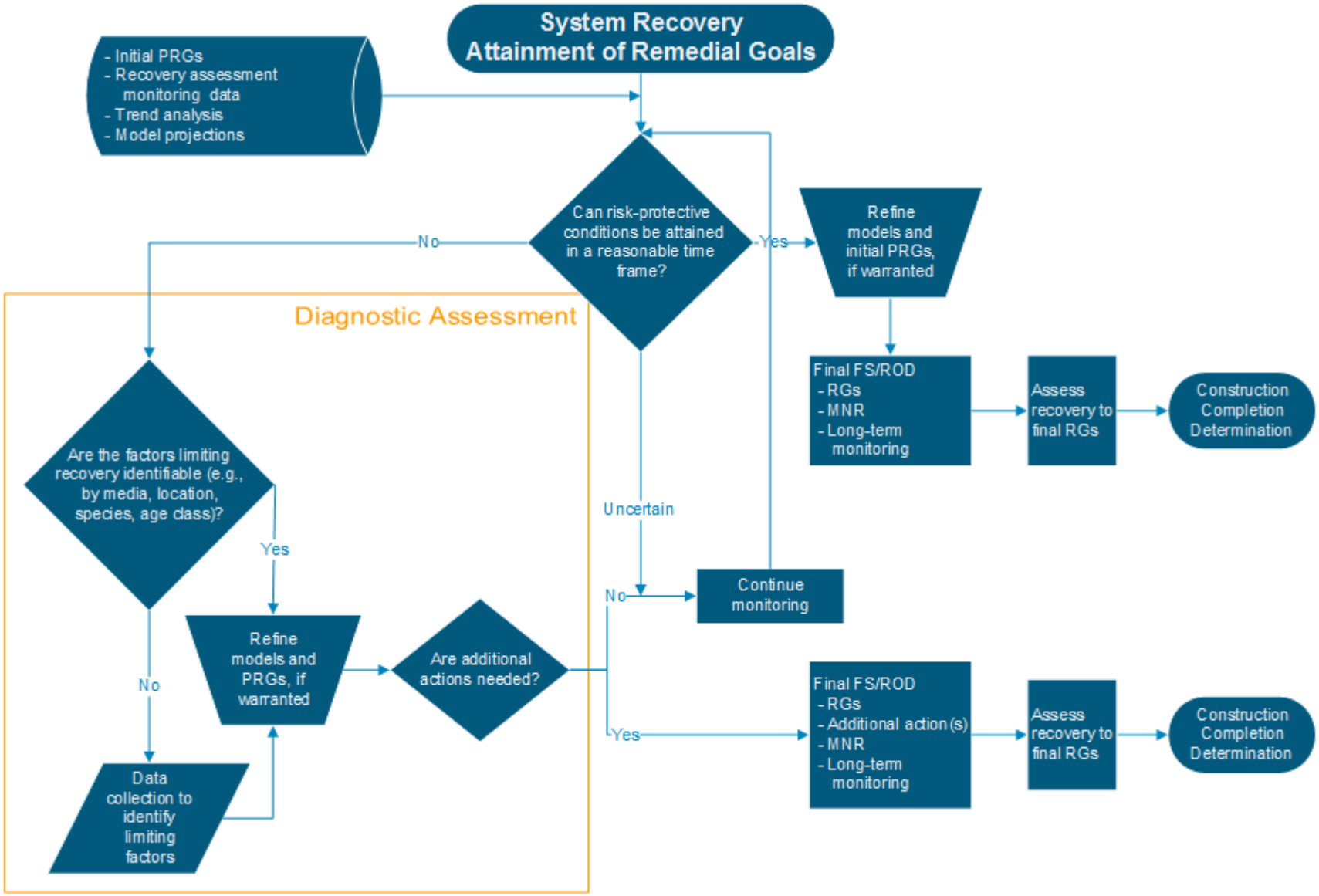

Figure 5-4.
Decision Tree: System Recovery—Attainment of Remediation Goals

Tables

Table 2-1. LPRSA Upper 9-Mile Adaptive Management Decision Framework

Adaptive Element	Decision Questions	Decision Time Frame(s)	Key Data Inputs	Criteria and Supporting Analyses for Decision-Making
1. IR Design and Implementation	#1: Does delineation of the IR FS footprint adequately capture sediment sources?	- During remedial design - During IR implementation - At IR completion	Current Conditions - Bathymetry - Water Column PDI - Sediment - Bathymetry	- Define acceptable uncertainty in IR footprint delineation - Conduct two-phase PDI sediment sampling to refine footprint to acceptable level - Apply refined numerical models to support identification of erosional areas if bathymetric data are insufficient
	#2: Was the IR successfully implemented and did it attain the IR FS RAOs upon completion?		Construction Monitoring - Water Column - Sediment - Bathymetry Post-IR - Sediment	- Trigger construction modifications if performance standards are exceeded - Assess any remaining sources/actionable sources - Determine if RAOs are achieved - Evaluate lines of evidence to determine remedy completion (see Appendix H)
2. System Response	#1: Does the post-IR system demonstrate improved recovery?	In conjunction with 5-year reviews, and/or at other times outside of 5-year review process if and as appropriate and beneficial to the program.	Current Conditions - Tissue - Water column - Bathymetry PDI - Sediment - Bathymetry Recovery Assessment Monitoring Data - Tissue - Water column - Sediment - Bathymetry	- Define pre-IR baseline concentrations - Define expected recovery trajectories during remedial design, based on refined CSM and numerical models - Collect recovery assessment monitoring data to evaluate recovery trends - Define acceptable statistical significance of observed trends - Perform trend analysis to assess system response - Modify recovery assessment monitoring program if data gaps identified

Table 2-1. LPRSA Upper 9-Mile Adaptive Management Decision Framework

Adaptive Element	Decision Questions	Decision Time Frame(s)	Key Data Inputs	Criteria and Supporting Analyses for Decision-Making
	#2: Is the system response consistent with the CSM and model projections of recovery?	In conjunction with 5-year reviews, and/or at other times outside of 5-year review process if and as appropriate and beneficial to the program.	Current Conditions - Tissue - Water column - Bathymetry PDI - Sediment - Bathymetry Recovery Assessment Monitoring Data - Tissue - Water column - Sediment - Bathymetry	- Trigger diagnostic assessment if observed recovery is inconsistent with expected recovery based on the CSM and numerical models - Refine CSM and/or numerical models, as warranted
3. System Recovery	#1: Is information available that suggests uncertainty in PRG inputs can be further constrained and that refinement of the PRGs is warranted?	In conjunction with 5-year reviews, and/or at other times outside of 5-year review process if and as appropriate and beneficial to the program.	Current Conditions - Tissue - Water column - Bathymetry PDI - Sediment - Bathymetry Recovery Assessment Monitoring Data - Tissue - Water column - Sediment	- Develop initial PRGs in conjunction with the remedial design - Identify the initial PRG input variables with the greatest uncertainty - Evaluate whether new information collected during recovery assessment monitoring reduces key uncertainties and warrants PRG refinement - Refine PRGs and present to decision makers, with information on uncertainty factors
	#2: Can risk-protective conditions be attained in a reasonable time frame?	In conjunction with 5-year reviews, and/or at other times outside of 5-year review process if and as appropriate and beneficial to the program.	Recovery Assessment Monitoring Data - Tissue - Water column - Sediment	- Establish acceptable time frames for recovery in conjunction with initial PRGs - Reevaluate acceptable time frames, if warranted, based on collection of several years of post-IR recovery assessment monitoring data - Trigger diagnostic assessment if recovery not progressing as expected - Recommend possible response options to decision makers based on diagnostic assessment outcomes

Notes:
CSM = conceptual site model
FS = feasibility study
IR = interim remedy
PDI = pre-design investigation
PRG = preliminary remediation goal
RAO = remedial action objective

Table 2-2. Overview of Sampling Activities and Objectives to Support Adaptive Management

Activity	Adaptive Management Objective	Sampling Media				
		Sediment	Biota	Water Chemistry	Physical Water	Bathymetry
Current Conditions	Documentation of baseline conditions prior to design and implementation of IR		✓	✓	✓	✓
Pre-Design Investigation	Delineation of IR footprint and documentation of baseline sediment conditions	✓				✓
Construction Monitoring	Evaluation of IR performance and confirmation of IR RAO attainment	✓	✓	✓	✓	✓
Post-IR Sampling	Evaluation of IR performance and confirmation of IR RAO attainment	✓				
Recovery Assessment Monitoring to Final ROD	Identification and documentation of post-IR recovery patterns and trajectories to attain PRGs; reevaluation of PRGs and/or establishment of final RGs	✓[a]	✓[b]	✓[b]	✓[b]	✓[a]
Diagnostic Assessment Sampling	Diagnostic assessment of factors influencing system response and/or inhibiting recovery	✓[c]	✓[c]	✓[c]	✓[c]	✓[c]
Long-Term Monitoring to NFA	Identification and documentation of post-final ROD recovery and attainment of final RGs.	✓[d]	✓[d]	✓[d]	✓[d]	✓[d]

Notes:
IR = interim remedy
NFA = no further action
PRG = preliminary remediation goal
RG = remediation goal
ROD = record of decision

[a] Sediment and bathymetry data will be collected periodically during long-term monitoring, following high flow events and at specified intervals.
[b] Biota and water column data will be collected annually during long-term monitoring.
[c] Data will be collected as needed to support a diagnostic assessment.
[d] Frequency of data collection will be established in the final ROD.

Table 5-1. Exposure Pathways, Risk Drivers, and Media for Establishing Preliminary Remediation Goals and Final Remediation Goals

Receptor/Exposure Pathway	Category	Risk Driver(s)[a]	PRG Medium[b]
Recreational Angler/Fish Consumption	Human Health	2,3,7,8-TCDD Total PCBs Methylmercury	Sediment, Fish Tissue
Recreational Angler/Crab Consumption	Human Health	2,3,7,8-TCDD Total PCBs	Sediment, Crab Tissue
Fish	Ecological	PCDD/PCDF and total TEQ[c] Total PCBs[c] PCB TEQ[c] Total DDx[c] Copper[d]	See note (b)
Birds	Ecological	PCDD/PCDF and total TEQ[c] Total PCBs[c] PCB TEQ[c] Total DDx[c] Copper[d] Mercury[d] Lead[d]	See note (b)
Mammals	Ecological	PCDD/PCDF and total TEQ[c] Total PCBs[c] PCB TEQ[c] Mercury[d]	See note (b)
Benthic Invertebrates	Ecological	PCDD/PCDF and total TEQ[c] 2,3,7,8-TCDD[d] Total PCBs[c] Total DDx[c] Dieldrin[d] Mercury[d] Copper[d] Lead[d] PAH[d]	See note (b)

Table 5-1. Exposure Pathways, Risk Drivers, and Media for Establishing Preliminary Remediation Goals and Final Remediation Goals

Notes:

[a] Human health risk is driven primarily by consumption of fish and crab containing the COC 2,3,7,8-TCDD, and to a lesser extent the COC PCBs, and ecological risks are primarily driven by exposure to the COCs PCDDs/PCDFs, PCBs, and DDx. These COCs and other COCs in this table have been identified as the chemicals for which PRGs/RGs should be developed. During the IR and monitoring subsequent to the IR, data may be collected so that some chemicals may be removed from the COC list by EPA; thus, at that time, potential further refinement of the PRG and development of an RG would not be warranted for the removed chemical(s).

[b] PRGs will be developed for sediment. Tissue concentrations may be developed for monitoring purposes and to support interim goals that facilitate communication of risk reduction to stakeholders, but will not be used as PRGs.

[c] Risk driver identified in the USEPA-approved LPRSA BERA (Windward 2019a).

[d] COC as directed by USEPA for the Current Conditions QAPP Addendum No. 7 (Windward 2019b) based on the USEPA-approved LPRSA BERA (Windward 2019a) and consistent with the Lower 8 mile Record Of Decision (USEPA 2016).

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

BERA = Baseline Ecological Risk Assessment

COC = chemical of concern

DDx = DDT and its metabolites

EPA = U.S. Environmental Protection Agency

FFS = Focused Feasibility Study

IR = interim remedy

LPRSA = Lower Passaic River Study Area

PAH = polycyclic aromatic hydrocarbon

PCB = polychlorinated biphenyl

PCDD/PCDF = polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran

PRG = preliminary remediation goal

QAPP = Quality Assurance Project Plan

RG = remediation goal

TEQ = toxicity equivalence

Table 5-2. Key LPRSA Uncertainties in PRG Development

Input	Discussion of Uncertainty
CFT model projections of sediment and water column concentrations	CFT projections are used in the FWM to establish sediment PRGs for fish consumption and project time for attainment of PRGs/RGs. CFT projection uncertainty informs a range of PRGs and recovery time frames. Refinement of the CFT model will support better estimates.
Tissue, sediment, and water column COC concentrations	Additional data collection (current conditions and post-IR sampling) will provide an opportunity to better characterize the complex relationships between COC concentrations in sediment, water, and tissue.
Fish movement	Fish movement varies across species and within a population as well as seasonally and with migratory behavior. Characterization of fish movement (e.g., fish tagging studies) supports refinement of the FWM with better input on exposure.
Benthic and water column COC exposure	The FWM calibration relies on the relative importance of exposure of biota to four carbon sources (water column particulate organic matter, near-bottom water column particulate organic matter, recently deposited particulate organic matter, shallow bedded sediment particulate organic matter); additional data collection could better characterize relative exposure.
FWM parameters that could be refined with additional data collection (e.g., growth rates, lipid content, and COC partitioning to algae)	Additional site-specific data collection of these parameters would reduce uncertainty and/or reliance on literature values.
FWM parameters that could be refined with refined model calibration (e.g., octanol–water partition coefficient [K_{OW}], dietary chemical transfer efficiency [E_D], metabolic rates [K_M])	These parameters are derived from the literature and are key parameters in model calibration. The updated empirical tissue data set and corresponding CFT model inputs will help refine calibrated parameter values. Whether there is more than a single acceptable value for these parameters will also be evaluated. Updated tissue data can also be used to assess the relative quality of alternative calibrations.

Notes:
CFT = contaminant fate and transport
COC = chemical of concern
EPA = U.S. Environmental Protection Agency
FWM = food web model
IR = interim remedy
LPRSA = Lower Passaic River Study Area
PRG = preliminary remediation goal

Table 5-3. Background Surface Water Concentrations

	Small Volume Chemical Water Column Monitoring Program[a]						High Volume Chemical Water Column Monitoring Program[b]	
	2,3,7,8-TCDD (pg/L)	4,4'-DDE (ng/L)	4,4'-DDD (ng/L)	4,4'-DDT (ng/L)	Mercury, Dissolved (ng/L)	Total PCBs (ng/L)	2,3,7,8-TCDD (pg/L)	Total PCBs (ng/L)
Mean	4.22	0.55	0.31	0.42	2.70	3.91		
Median	4.22	0.58	0.35	0.36	2.43	4.21		
Min	4.22	0.16	0.10	0.11	0.60	0.03	0.009	1.85
Max	4.22	0.83	0.49	0.87	7.66	11.10	0.012	2.57

	NJ WQS[c]					
Criterion	2,3,7,8-TCDD (pg/L)	4,4'-DDE (ng/L)	4,4'-DDD (ng/L)	4,4'-DDT (ng/L)	Mercury, Dissolved (ng/L)	Total PCBs (ng/L)
Freshwater (HH)	0.005 (hc)	0.22 (hc)	0.31 (hc)	0.22 (hc)	50 (hT)	0.064 (hc)
Saline (HH)	.0051 (hc)	0.22 (hc)	0.31 (hc)	0.22 (hc)	51 (hT)	0.064 (hc)
Freshwater (Aq)				1	770 (ds)	14
Saline (Aq)				1	940 (ds)	30

Notes:

Nondetects not included; field duplicates included as unique samples.

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

Aq = Aquatic

d = Criterion is expressed as a function of the water effect ratio (WER). For criterion in the table, WER equates to the default value of 1.0.

DDD = 4,4'-dichlorodiphenyldichloroethane

DDE = 4,4'-dichlorodiphenyldichloroethylene

DDT = 4,4'-dichlorodiphenyltrichloroethane

h = human health noncarcinogen

hc = human health carcinogen

HH = human health

PCB = polychlorinated biphenyl

s = dissolved criterion

T = total recoverable criterion

[a] AECOM. 2019. Small Volume Chemical Water Column Monitoring Sampling Program Characterization Summary – Lower Passaic River Study Area RI/FS.

[b] AECOM. 2019. High Volume Chemical Water Column Monitoring Sampling Program Characterization Summary – Lower Passaic River Study Area RI/FS.

[c] New Jersey Department of Environmental Protection, Surface Water Quality Standards, 2020

APPENDIX E
LESSONS LEARNED FROM EARLY ACTIONS ON THE LOWER PASSAIC RIVER

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

Prepared for
Lower Passaic River Cooperating Parties Group
New Jersey

Prepared by

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September 2021

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
COPC	chemical of potential concern
CPG	Lower Passaic River Cooperating Parties Group
cy	cubic yard
EPA	U.S. Environmental Protection Agency
hp	horsepower
IR FS	interim remedy feasibility study
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
OCC	Occidental Chemical Corporation
PCB	polychlorinated biphenyl
RM	river mile
UPF	Upland Processing Facility

1 INTRODUCTION

The physical setting, hydrologic characteristics, and highly urbanized environment of the Lower Passaic River Study Area (LPRSA) introduce significant challenges and constraints to the implementability of sediment dredging, capping, and transport on the Lower Passaic River (LPR). Experience gained from the 2013 River Mile (RM) 10.9 removal action performed by the Cooperating Parties Group (CPG) and the 2011 Phase 1 removal action performed by Occidental Chemical Corporation (OCC) on the LPR provides useful information regarding constructability and informed the development and evaluation of remedial alternatives for the upper 9-mile interim remedy feasibility study (IR FS).

There are 20 fixed and movable bridges along the LPR between RM 1.2 and RM 14.7 (Table 1; Figure 1), with vertical clearances ranging from 5 to 135 ft. The transport of dredged sediments, backfill materials, and equipment during remedial action along the LPR may necessitate numerous individual openings of movable bridges to permit passage of tugboats and barges. While methods to minimize openings will be evaluated during the remedial design, it is important to note the conditions of the bridges for consideration during planning and design. The bridges on the LPR are aged, the majority are deemed structurally deficient, and repeated openings have the potential to cause mechanical failures, which could limit further bridge openings for periods of days or months, restricting barge movement and dredging activities upriver of the inoperable bridge. Moreover, in the event bridges remain open during failures, significant regional transportation impacts will result, affecting thousands of commuters daily. Accordingly, this appendix also presents information on bridge conditions, navigational factors, and tug and operational barge requirements, based on research of publicly available information and interviews with tug pilots and others experienced with tugboat and barge operations on the LPR.

The factors identified in this appendix may impact the overall duration and cost of the interim remedy, and could impose long-term stresses on the surrounding community and environment. These impacts will increase in general proportion to the volume of sediment removed and associated transport and placement of backfill materials under each remedial alternative. For this reason, information from past projects and tug and barge operator experience was considered in the IR FS for the purpose of making reasonable assumptions regarding equipment selection (e.g., barge size), dredge production rates, and associated development of estimated construction durations and costs. These selections for the purposes of the IR FS do not preclude evaluation of alternative methods and/or equipment during the remedial design. For example, hydraulic transport of dredged material is reportedly under evaluation in the remedial design for the lower 8-mile remedy to reduce the need for bridge openings and may be considered for the upper 9-mile IR based on the lower 8-mile evaluation. During the remedial design, options would be explored and efforts put forth to address the issues and challenges discussed in this appendix.

2 RM 10.9 REMOVAL ACTION

The CPG performed the removal and disposal of 15,742 cubic yards (cy) of the top 2 ft of sediment taken from a mudflat at RM 10.9 of the LPR followed by the construction of an engineered multi-layer cap. The objective of this work was to remove surficial sediments with elevated concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), polychlorinated biphenyls (PCBs), and other chemicals of potential concern (COPCs) and cap the remaining sediments in place to reduce the potential for exposure to receptors and to prevent potential migration of contamination from the RM 10.9 removal area. The RM 10.9 removal action, which was conducted under the authority of the Comprehensive Environmental Response, Compensation and Liability Act as a time-critical removal action, was initiated in July 2013; the removal of sediments was completed on October 4, 2013, followed by capping, which was completed on May 29, 2014.

2.1 BRIDGE OPENINGS

Fifteen bridges (13 movable and 2 fixed) are located on the LPR downstream of the RM 10.9 project area (Table 1, Figure 1). The RM 10.9 removal action required coordination of openings of nine low-clearance bridges on the LPR to allow passage of tugs, barges, and dredging equipment. There were 104 one-way trips, requiring 936 individual transits of movable LPR bridges that were opened over the duration of the project.

Implications: Based on the number of daily bridge openings required during the RM 10.9 removal and the number of days estimated for the IR FS alternatives, up to 18,000 individual bridge openings could be required to implement the proposed IR FS alternatives, depending on methods and equipment sizing assumptions. Multiple daily bridge openings will cause significant traffic disruptions to the surrounding communities.

2.2 BRIDGE MECHANICAL CONDITIONS, MAINTENANCE, AND OPERATIONS

Based on information presented in the RM 10.9 Final Construction Report (CH2M Hill 2019), delayed bridge repairs and additional mechanical and electrical problems resulted in unscheduled failures of bridges to open, causing delays of 42 days (6 weeks) in the removal action schedule. Bridge operational problems during periods of very low temperatures and extreme winter weather were also identified as contributing factors to 36 days (approximately 5 weeks) of additional project delays. The Bridge Street Bridge was inoperable at the initiation of the RM 10.9 removal action and experienced significant mechanical problems during the project. Openings of the Amtrak Dock Bridge and the New Jersey Transit Stickel Bridge were restricted during rush hours; barges could be moved only during each day's high tides, and movement was delayed when high tides occurred during rush hours. Openings of other

bridges were restricted due to community events at local venues (e.g., the Red Bull Arena in Harrison).

The Code of Federal Regulations (Title 33 § 117.739) specifically defines the notification times and requirements associated with bridge openings. In addition, § 117.739 states that the following bridges are not required to open during certain hours:

> (e) The draw of the Amtrak Dock Bridge, mile 5.0, at Harrison, shall open on signal after at least a twenty-four hour advance notice is given by calling the number posted at the bridge; except that, from 7:20 a.m. to 9:20 a.m. and from 4:30 p.m. to 6:50 p.m., Monday through Friday, except Federal holidays, the draw need not be opened for the passage of vessel traffic. At all other times, a bridge opening may be delayed no more than ten minutes for the passage of rail traffic, unless the draw tender and the vessel operator agree to a longer delay.
>
> (g) The draw of the NJTRO Newark-Harrison (Morristown Line) Bridge, mile 5.8, at Harrison, New Jersey shall open on signal if at least one hour advance notice is given to the drawtender at Upper Hack Bridge mile 6.9, across the Hackensack River at Secaucus, N.J. In the event the HX drawtender is at the Lower Hack Bridge, mile 3.4 on the Hackensack River, at Jersey City then up to an additional half hour delay in opening is permitted. After the signal to open is given, the opening may be delayed no more than ten minutes. From 7:15 a.m. to 9 a.m. and from 4:30 p.m. to 6:50 p.m., Monday through Friday except federal holidays, the draw need not open.
>
> (p) The draw of the Route 1 & 9 (Lincoln Highway) Bridge, mile 1.8, between Kearny and Newark, shall open on signal if at least a four hour advance notice is given; except that, the draw need not open for the passage of vessel traffic between 6 a.m. and 10 a.m. and between 2 p.m. and 6 p.m., Monday through Friday, except holidays. Tide dependent deep draft vessels may request bridge openings between 6 a.m. and 10 a.m. and between 2 p.m. and 6 p.m., provided at least a twelve hour advance notice is given by calling the number posted at the bridge.

These federally mandated restrictions may result in significant daily time periods when barge traffic on the LPR may be restricted and remedial activity impacted.

Implications: Delayed bridge openings due to operational or mechanical issues will impede barge movement up and down the river, potentially extending the duration of the dredging and capping activities. The operating condition of aged bridges will require further evaluation during remedial design, and significant infrastructure upgrades and/or frequent maintenance may be required for bridges to be operational during remedy implementation. Many of the bridges that span the LPR are structurally deficient (Table 1). Planning efforts are also under way to replace the DeJessa-Avondale Street (Kingsland Avenue) Bridge. Navigation could be restricted for several months during bridge reconstruction. Five bridges below RM 11 have

vertical clearance of 15 ft or less at high tide, and will require opening for passage of barges and tugs regardless of equipment selection.

2.3 NAVIGATIONAL CONSTRAINTS

Tides, currents, channel width and depth, limited bridge clearances, obstructions, shoals, and outcrops restrict navigation and impact equipment sizing and timing of barge movement. Navigation through bridge openings is impeded by outcrops and currents, and must be coordinated with tides. Upstream of the Jackson Street Bridge (RM 4.6), channel and bridge constraints are very restrictive. Specific constraints include:

- Five movable bridges below RM 11 (Bridge Street, Morristown Line Railroad, Clay Street, Rutgers [Route 7] and DeJessa-Avondale Street (Kingsland Avenue) have vertical clearance of 15 ft or less at high tide, and will require opening for passage of tugs and barges regardless of equipment selection.
- Horizontal openings of several bridges are very restrictive. Two bridges (Erie/Montclair-Greenwood Lake Railroad and Lyndhurst-Delaware Rail) have less than 50 ft horizontal clearance. Following guidance of the U.S. Army Corps of Engineers (USACE 2006), these clearances reduce maximum advisable barge width for passage to less than 30 ft.[1]
- Strong currents exist, particularly during spring runoff.
- The overall channel width narrows, limiting the room for staging and maneuvering scows and requiring the use of smaller dredges and barges.
- A rock outcrop exists at RM 8, narrowing the navigational channel, increasing currents, and necessitating a sharp turn to maneuver past the outcrop.
- Water depths limit the vessel draft to 10 ft for safe navigation through shallower areas, limiting the allowable barge capacity and loads, and requiring barge movements to occur during limited periods around high tides.[2]
- High water velocities require sufficiently powered tugboats to navigate the barges around bridge structures and shoal areas, restricting the opportunities to use smaller vessels, and likely eliminating the ability to transport multiple barges with a single tug.

Implications: Channel width and depth and bridge constraints limit the size and number of dredges and barges that can operate on the LPR above RM 8.3 and, together with tugboat horsepower requirements, limit the type of equipment suitable for operations on the LPR. CPG's cost and duration estimates for the IR FS are based on the assumption that only a single

[1] Barges with a 40-ft width were used for the RM 10.9 removal, allowing 8 ft of clearance through the Erie/Montclair-Greenwood Lake Railroad Bridge at RM 8.1 and creating a significant navigational challenge.
[2] Above RM 8.1, loaded barge volume is likely limited to approximately 500 cy, based on the RM 10.9 removal.

dredge would operate at a time upstream of RM 8.3,[3] and that dredge and barge capacities would be limited.

2.4 UTILITIES

Accurate location of utilities is a challenge, and utility setback requirements will create multiple "no dredge zones." At RM 10.9, a subbottom profile survey and a magnetometer survey were performed to determine the lateral location and depth of a buried water line. The depth was not accurately determined because of the poor ability to detect a concrete line, and there was some uncertainty regarding its lateral location. A sediment probing investigation was performed by Tierra (OSI 2015) in the vicinity of the water line location; the results were consistent with the previous survey, with some additional characterization of pipe elevation, although the exact location of the water line remained uncertain. The surveyed lateral location was offset approximately 10 ft from the mapped location. Because of this uncertainty in the survey results, the utility was unwilling to rely on the geophysical survey when determining from where the setbacks should begin, and would not reduce the buffer to less than 30 ft on either side of the estimated pipeline alignment.

Implications: Numerous utility corridors exist within the upper 9 miles of the LPRSA (Figure 2). The location of utilities will be a significant design task to identify any additional utilities and to locate more precisely and determine appropriate dredging offsets, if necessary. Utility corridors will need to be considered in the design dredge prism calculations.

2.5 HARDENED SHORELINES/HARD SUBSURFACE CONDITIONS

Hardened shorelines and hard subsurface conditions were encountered in the RM 10.9 removal area and resulted in lower production rates and incomplete removal around the hardened areas. These conditions, along with the substantial debris in LPR sediments (based on the Phase 1 removal action, approximately 7 percent of the *in situ* dredge volume consists of debris), impacted equipment selection and production rates and resulted in unanticipated construction delays.

Implications: Based on the 2013 survey of shoreline conditions (AECOM 2015), significant portions of the upper-9 mile LPR shoreline consisted of riprap and bulkhead (Figure 2). In addition, offsets from bulkheads, structures, and riprap shorelines will be developed during remedial design, with larger offsets considered for safety where the shoreline is in poor

[3] The actual dredging methods will be determined during the design and bid process, and could include multiple dredges operating simultaneously. Due to space and potential equipment and processing limitations, a single dredge is assumed for the IR FS.

condition. Dredge prisms during design will have to include provisions for dredging offsets from hardened shorelines.

In addition, river bottom features such as debris, moorings, and wrecks have been documented in the LPR (ASI 2006). Most commonly, these include the remains of wrecked vessels, cars, or other large debris, or pilings or dolphins used for mooring vessels. Large boulders/stones are evident in some areas and visible at low tide along the shoreline.

Dredge production rates will be impacted by shoreline structures and other waterway conditions, in addition to the navigational constraints and utility corridor issues discussed above.

2.6 RESIDUALS CONTROL

Silt curtains were installed to control potential resuspension during the RM 10.9 dredging operations. The silt curtains were designed to be flexible and adaptable to river and dredging conditions (CH2M Hill 2019). Silt curtains were installed in three campaigns, requiring relocation twice during the removal activities. Results of water quality monitoring during dredging indicated no exceedances of trigger or action levels, and no statistically significant differences between pre-dredge baseline and dredging sample averages were found (CH2M Hill 2019).

Implications: Residuals can be successfully controlled with silt curtains and/or other methods. The use of silt curtains may extend construction durations, as they are time consuming to relocate during construction. Silt curtain applications are limited by water depth and ambient currents. Residual control, including appropriate dredging technologies and best management practices, will be established during remedial design.

2.7 FISH MIGRATION WINDOW

During the RM 10.9 removal action, the National Marine Fisheries Service guidance restricted in-river construction activities from mid-March through June. Only the capping phase of the removal action was performed during this period, and the New Jersey Department of Environmental Protection, after discussions with U.S. Environmental Protection Agency (EPA) Region 2, opted not to enforce the fish window for the capping operations, given their less disruptive nature (CH2M Hill 2019). During OCC's Phase 1 removal action on the LPR, EPA accepted the recommendation of the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration to establish a fish migration window that precluded dredging from March 1 to June 30. It is anticipated that similar restrictions would be adopted for future

remedial actions on the LPR. The dates of the fish window(s) precluding construction activity will be set prior to scheduling those actions.[4]

Implications: The IR FS assumes dredging will occur for 26 weeks, accounting for the 17-week fish window and an estimated 9-week shutdown period that could be necessitated by weather and/or operational delays. Fish window restrictions will significantly increase the duration of the dredging activities, nearly doubling the total project duration.

2.8 CONSTRUCTION MONITORING

Development and implementation of a construction monitoring program was challenging at RM 10.9 because of the existing, degraded status of the ambient water quality and the temporal variations in water quality driven by the tidal influence. Achieving consensus with the agencies on a program focused on potential dredging and capping impacts alone was difficult. Turbidity spikes were observed in the water column monitoring data that were not related to dredging activities, but likely from runoff and other background sources and tidal flow variations. Water column data collected during the remedial investigation indicated ambient COPC concentrations above water quality criteria in the LPR and above Dundee Dam.

Implications: Development and acceptance of a construction monitoring program that isolates potential water quality exceedances due to dredging/capping activities will be a challenge. Misinterpretation of the monitoring data could lead to unwarranted project shutdowns, resulting in schedule delays and/or implementation of unnecessary controls.

2.9 PERMITTING

The RM 10.9 removal action required permits/permit equivalents from multiple agencies including New Jersey's Tidelands Licenses and Waterfront Development Permits, which have provisions for notification of property owners adjacent to the work area. The process was a critical path task and took several months to complete. Communities along the river and bridge operators also imposed additional notification and coordination requirements beyond those of the New Jersey Department of Environmental Protection.

Implications: The permitting process for a large-scale removal has the potential to delay the initiation of dredging activities, as issuance of permit equivalents requires notice of all landowners adjacent to the river followed by a public statement period to grant access.

[4] The RM 10.9 removal was scheduled to avoid construction during the fish window period; however, due to project delays, a waiver was obtained to allow for completion of cap construction. The waiver was granted on the grounds that the work performed during the fish window was limited to cap construction, and did not include dredging.

2.10 LONG-TERM MONITORING PLAN

Design of the long-term, post-construction monitoring plan for the RM 10.9 removal required identification of appropriate metrics and methods to monitor cap performance. Lengthy discussions about the extent of the monitoring survey (i.e., number of samples), frequency, and methods necessary to assess cap performance delayed performance of the initial, baseline monitoring survey.

Implications: The long-term monitoring plan needs to be developed during the design phase, such that metrics and methods are established prior to implementation of a remedial action. The long-term monitoring approach should be established in conjunction with the cap performance monitoring plan to ensure compatibility of methods.

3 PHASE 1 REMOVAL ACTION

Under a Settlement Agreement executed on June 23, 2008, by and between the EPA, OCC and Tierra Solutions, Inc., OCC agreed to fund and perform the removal and disposal of 200,000 cy of LPR sediment located adjacent to Operable Unit 1 of the Diamond Alkali Superfund Site, located at 80 and 120 Lister Avenue, Newark, New Jersey, at approximately RM 3.4 of the LPR. On January 9, 2009, EPA, in consultation with the New Jersey Department of Environmental Protection, issued an Action Memorandum and selected the final plan for the first phase of this non-time-critical removal action (Phase 1). The remedial design for Phase 1, which addressed the most elevated dioxin-contaminated sediments from the LPR in the immediate vicinity of the Lister Avenue site, was finalized in July 2011, with implementation conducted from October 2011 to January 2013.

The Phase 1 removal action included removing and disposing of approximately 40,000 cy of LPR sediment located within the Harrison Reach of the LPR study area at approximately RM 3.4. The Phase 1 work area was approximately 2 acres and located adjacent to the federal navigation channel with an authorized depth of –22.4 feet National Geodetic Vertical Datum of 1929. Generally, the Phase 1 work area sediment was fine-grained, cohesive material classified as moderate to high plasticity organic silt and clay. The average flow near the Phase 1 work area is approximately 1,450 cubic feet per second and experiences approximately a 6-ft tidal fluctuations resulting in exposure of the work area during low-tide conditions.

3.1 SITING OF AN UPLAND PROCESSING FACILITY

The Upland Processing Facility (UPF) for the removal action was located on the former Fairmount Chemical site (owned by Morris Fairmount Associates, LLC) located at 117 Blanchard Street in Newark, New Jersey, approximately 1,400 ft downstream of the Phase 1 work area. A UPF performed sediment dewatering and water treatment and handled the dewatered sediment for offsite shipment. Identification of an adequate site for the UPF was a major technical, economic, and administrative challenge for the project (Romagnoli et al. 2013a). Requirements for the UPF site were shoreline access for conveying dredged material to the sediment dewatering plant, sufficient size for the equipment and logistics associated with offsite transportation of the material, and soils of sufficient bearing strength to withstand the loads associated with the sediment dewatering equipment and tanks used for the water treatment plant. Initially, several potential UPF sites were identified and evaluated, and during preliminary design, a site was selected. However, during final design and 3 months prior to construction, the UPF site was changed due to lease negotiations (Reed et al. 2013; Romagnoli et al. 2013a).

Implications: If needed, identification of a site and real estate arrangements should be pursued early and aggressively.

3.2 BRIDGE OPENINGS

During the construction (pre-dredging) phase of the project, transport of sheetpile-related construction materials and equipment to the Phase 1 work area via barge was delayed due to the closure of the Lincoln Highway Bridge, resulting in a 2-month delay in transporting construction materials and equipment to the site, and forcing resequencing and acceleration of construction work to maintain the dredging schedule (Romagnoli et al. 2013b).

Implications: As discussed above, the requirement to open some or all of the numerous low-clearance bridges along the LPR to move equipment, construction materials, and dredged sediments may lead to significant project delays.

3.3 AIR EMISSIONS

During design, it was determined that air emissions and odors could potentially be generated during site construction, dredging, material handling, and processing. Controls were implemented to satisfy regulatory requirements, and a perimeter air-monitoring program was developed to monitor PCBs, dioxins, dichlorodiphenyltrichloroethane (DDT), and chlorobenzene at the Phase 1 work area, the UPF, and two nearby residential areas (Romagnoli et al. 2013a). In addition, community outreach and contingency plans were developed proactively (Reed et al. 2013).

Implications: Both the Phase 1 and RM 10.9 removal actions required extensive air emission monitoring. Exceedances detected during monitoring could impact the dredging schedule, even if the exceedances are not related to the dredging activities.

3.4 DEBRIS

Significant debris was encountered during the Phase 1 removal (Romagnoli et al. 2013b). Multisensor geophysical surveys were performed to identify potential debris within the removal area. Even with the various geophysical surveys, unidentified debris was still encountered during dredging. Large concentrations of metallic debris, ranging from small materials, such as nails and bolts, to larger pieces up to 6 in. long, were found in some areas and frequently clogged the trommel screen. The handling of this material significantly reduced productivity. The quantity and size of this debris caused additional complications for restrictions associated with the incinerator. Therefore, a debris washing operation, consisting primarily of mechanical equipment, static screens, and high-pressure water, was established at the UPF site to separate sediment from the oversized debris. In addition, long, thin debris (e.g., thin diameter metal rods and nails) occasionally passed through the trommel screen, which could accumulate and hang up in the pipeline used in the Phase 1 removal to transport sediment slurry to the processing facility. Additional measures were taken to prevent these blockages, such as periodically backwashing the line and adjusting the flow.

White phosphorus, a highly reactive material, was unearthed during the dredging, resulting in temporary work shutdowns and necessitating immediate mitigation measures to address fire and inhalation hazards (Romagnoli et al. 2013b). Self-combustion of the white phosphorus occurred on the barges, ranging from small areas of smoldering to open flames. Materials observed containing white phosphorus were separated and temporarily stored in steel drums filled with water for eventual offsite disposal.

Implications: The presence of significant debris in the LPR can impact dredge production rates and will necessitate debris management activities, including screening, washing, transport, and disposal. Contingencies for unexpected debris should be in place before dredging activities begin to minimize potential delays to construction activities.

4 TUGBOAT AND BARGE OPERATOR EXPERIENCE

Navigational constraints and the need for multiple bridge openings on the LPR will impact the selection of equipment and the passage of tugboats and barges to transport dredged sediments, backfill material, and equipment. Additional information on navigational factors and tug and barge requirements for operations on the LPR was obtained based on research of publicly available information and interviews with tug pilots and others experienced with tugboat and barge operations on the LPR (Table 2). Specific areas of inquiry included:

- Tugboat and barge specifications to meet LPR navigational requirements
- Confirmation of and additional inquiry regarding navigation through restricted bridge openings on the LPR
- Availability of tugboats and barges that meet LPR navigational requirements
- Specification of equipment used during the RM 10.9 removal action and decision factors around that selection.

As discussed below, experience from pilots who have worked on the LPR suggests specific minimum tugboat and barge requirements for operations on the LPR.

4.1 TUGBOATS

Experience of tugboat pilots on the LPR provides site-specific information on the equipment best suited to the challenges and constraints of operation on the river. Recommendations on equipment most appropriate for work on the LPR varied among pilots, although there were some commonalities in opinions on the LPR conditions and constraints.

Tugboats must be able to maneuver through narrow passages (e.g., the rock outcrop at RM 8 and the narrow bridges openings) and stop and hold a barge safely during transit (e.g., while approaching a bridge as it opens). The tugboat horsepower (hp) and number of screws determine the maneuverability of the tug. Pilots familiar with the LPR recommended a minimum of 1,000 hp to 1,600 hp (although one pilot suggested that a lower power could be adequate as well) and two screws for efficient navigation. Larger tugs, with a greater draft, could be counterproductive on the LPR.

Tugboats used on the RM 10.9 removal action are summarized in Table 3. The selection of tugboats was based in part on regional availability of equipment. In the initial contract specifications for the project, the maximum height of on-water equipment was 17 ft. During the project, the height specification was increased to 35 ft (air draft requirement to meet the vertical clearance of the Erie/Montclair-Greenwood Lake Railroad Bridge, which is no longer in use and fixed in closed position). In general, tugboats in the region have a vertical clearance on the order of 30 ft. There are relatively few that could pass under the Amtrak Dock Bridge and the

Lyndhurst-Delaware Rail Bridge in their closed position (24 and 26 ft vertical clearance, respectively).

Implications: Fabrication of custom tugboats designed to meet the specific navigational challenges of the LPR and/or retrofitting of available vessels may be a potentially viable and cost-effective option. For example, for the Hudson River dredging project, a fleet of custom tugboats was deployed. A fleet of dedicated tugboats may be cost-effective for a large dredging project and would ensure equipment on-hand at all times during the construction season but would however require long lead time for fabrication, and schedule constraints may preclude this option. Custom tugboats would not eliminate the need for bridge opening of several bridges, and would not overcome the need to move dredged material by barges only during high tide conditions.

4.2 BARGES

A range of barge sizes can be considered for use on the LPR, depending on the river sections that will be transited. Smaller barges will be required above RM 8 due to shallow water depths, narrow channel, and narrow bridge openings. During the RM 10.9 removal action, large (3,000 cy, 40-ft wide by 150-ft long, 17.5-ft maximum draft) barges were used initially (Table 3). Later in the project, smaller barges (formerly owned by the City of New York Department of Sanitation, now owned by local marine transportation companies) were used. These barges were preferred by the pilots; they are ~37-ft wide by 150-ft long, and have a low profile bulkhead, facilitating navigation along the river (empty air draft of 10 ft). The Department of Sanitation barges were reportedly used to move sediment quantities of approximately 900 tons per load. They are generally the smallest barges available in the region. Several of them are in service in the area and would likely be available to support future dredging projects on the LPR. The use of high bulkhead barges could require a higher operator height on the tugboat, and the use of longer barges would present navigational challenges at the rock outcrop at RM 8. It was the general consensus of the pilots that below RM 8, barges up to 3,000 cy could be used to transport dredged material down river.

Implications: Barge sizes for transporting contaminated sediments during future remediation on the LPR will be dictated by navigational factors and compatibility with dredge production rates. As with tugboats, custom barges could be fabricated to facilitate navigation. However, even custom equipment will not eliminate the need for openings of several low-clearance bridges at high tide.

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Figures

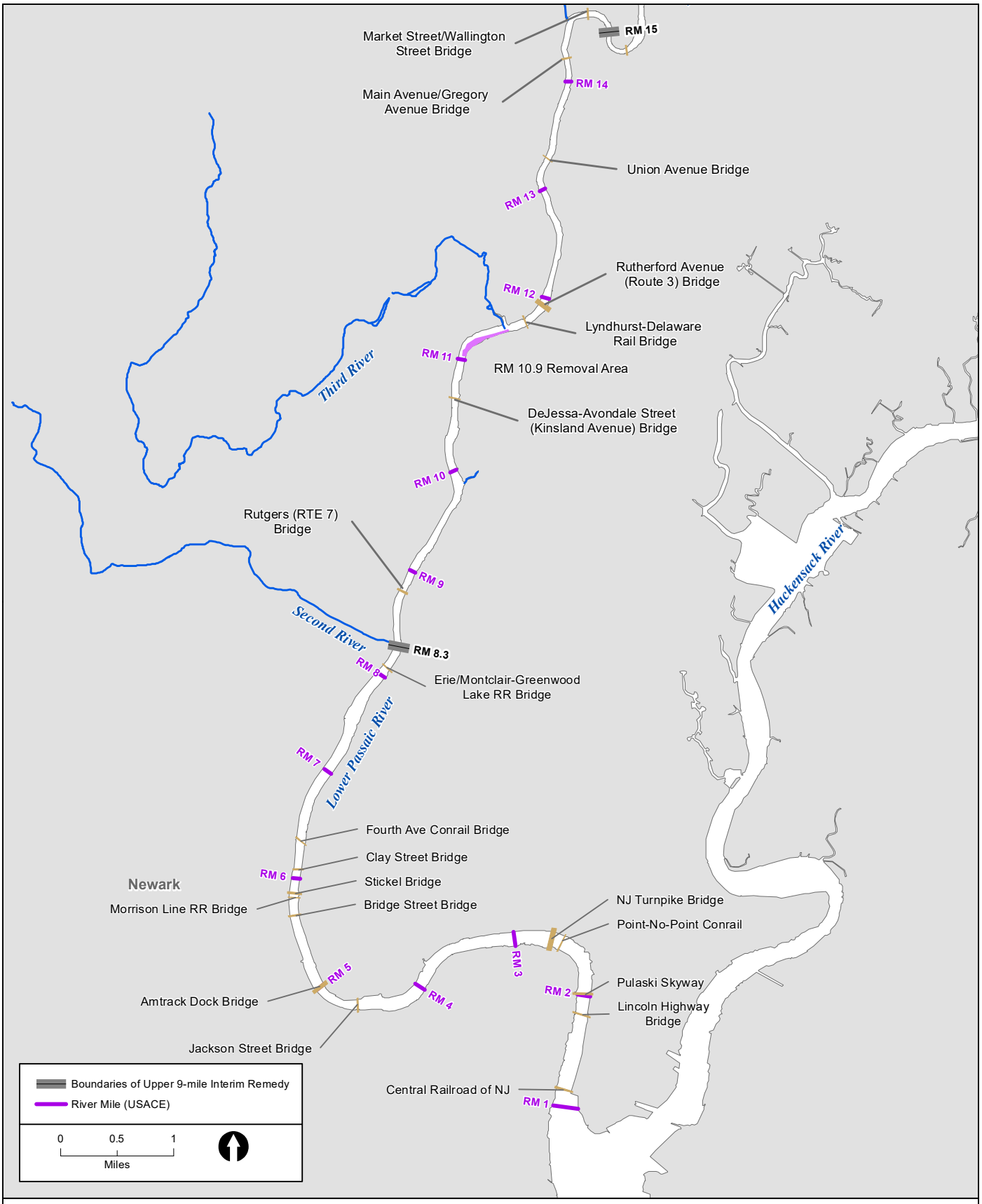

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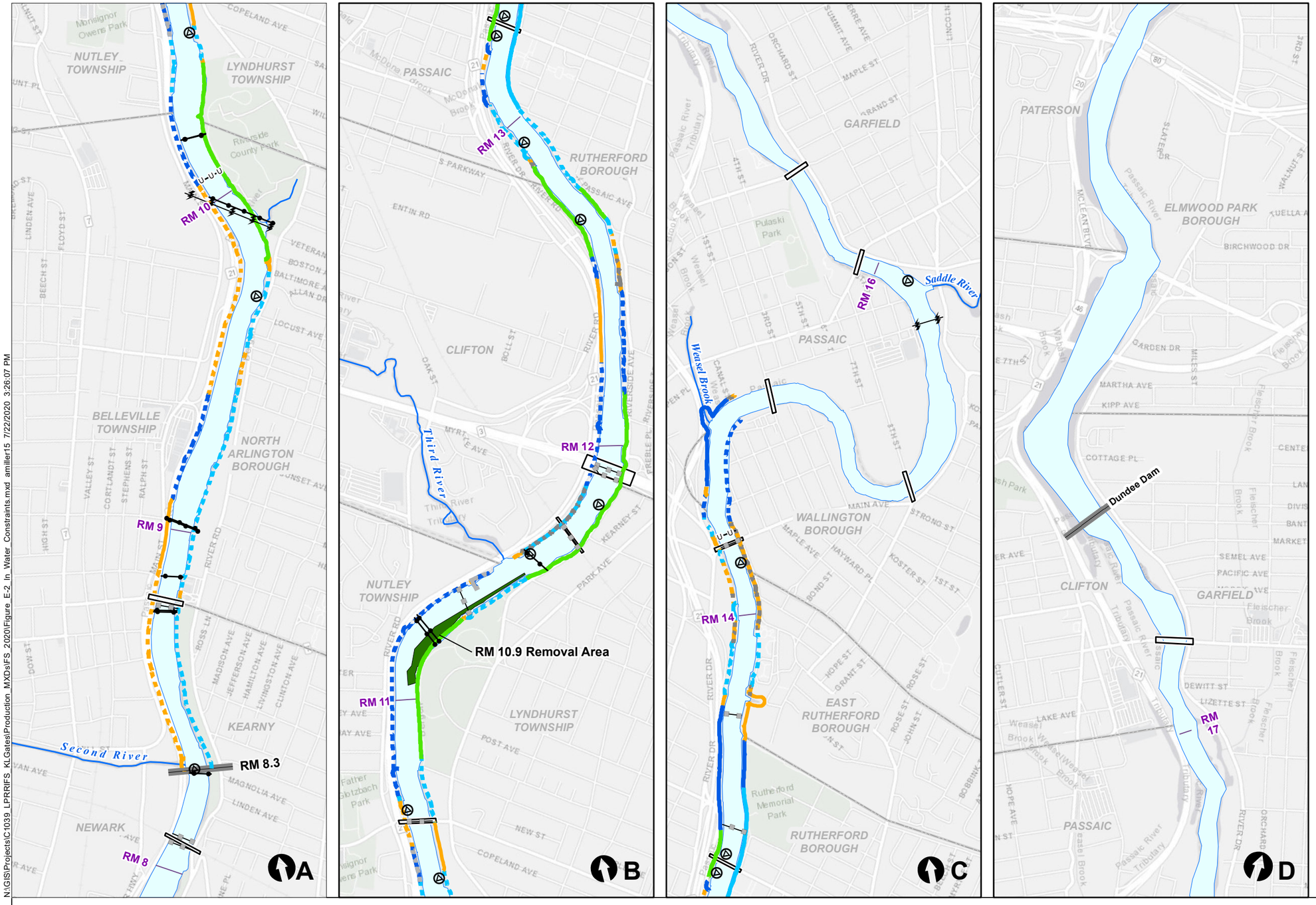
Figure 1.
Bridges of the Lower Passaic River
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study



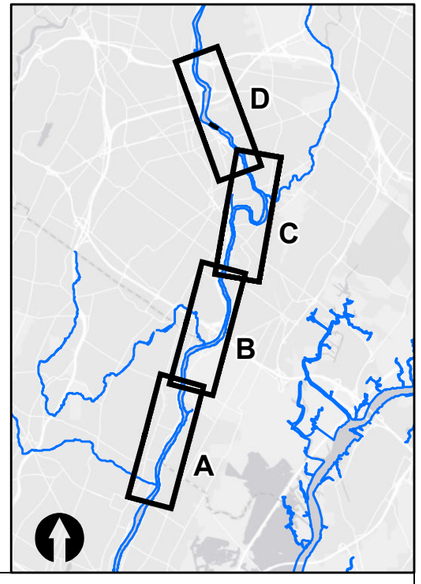
Shore Type, Condition

- Bulkhead, Poor to Failing
- Bulkhead, Fair
- Bulkhead, Good
- Engineered Riprap, Poor to Failing
- Engineered Riprap, Fair
- Engineered Riprap, Good
- Nonengineered Riprap, Poor to Failing
- Nonengineered Riprap, Fair
- Nonengineered Riprap, Good
- Natural; Natural, Fair
- Debris
- Cable Utility Crossing
- Pipeline Utility Crossing
- Unknown Utility Crossing
- Cable Overhead
- Upper 9-mile Study Area Boundary
- Lower Passaic River
- River Mile (USACE)
- Municipal Boundary
- Bridge

Note:
Bridge abutments, utility areas, debris, and shoreline structures (e.g., riprap, bulkheads, piers) may require safe dredging offsets and/or engineering controls to avoid damage to infrastructure. Dredging offsets would be based on structure/material type, condition, and adjacent structures and roadways.

River miles in USACE system. The RM 10.9 Removal Area was named in the RI RM system which differs from the USACE RM system by about 0.2 to 0.3 miles.

Basemap Source: Esri World Ocean Base



0 750 1,500
Feet

Figure 2.
Summary of Waterways Condition Assessment in the Upper 9 Miles
Upper 9-Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area Remedial Investigation and Feasibility Study

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Tables

Table 1. Characteristics and Conditions of Bridges on the Lower Passaic River

Bridge Name	Owner	FNC River Mile	Bridge Type	Maximum Horizontal Clearance (ft) [a]	Vertical Clearance at Mean High Water (ft) [a]	Condition Ratings[a]	Opened during RM 10.9 Removal Action Barge Operations
Point-No-Point Reach							
Central Railroad of New Jersey	NA	1.2	Lift	145	NA	Out of service	No
Lincoln Highway Bridge	NJDOT	1.85	Lift	300	35 (135)[b]	Deck: Satisfactory Superstructure: Fair Substructure: Fair Condition: Fair	No
Pulaski Skyway	NJDOT	2	Fixed	450	135	Deck: Poor Superstructure: Poor Substructure: Fair Condition: Poor Structural Evaluation Appraisal: Minimum tolerable	No
Harrison Reach							
Point-No-Point Conrail	Conrail	2.6	Swing	103	16	N/A	Yes
New Jersey Turnpike Bridge	NJDOT	2.7	Fixed	300	110	Deck: Satisfactory Superstructure: Fair Substructure: Good Condition: Fair	No
Newark Reach							
Jackson Street Bridge	City of Newark	4.6	Swing	73	15	Deck: Satisfactory Superstructure: Fair Substructure: Fair Condition: Fair	Yes

Table 1. Characteristics and Conditions of Bridges on the Lower Passaic River

Bridge Name	Owner	FNC River Mile	Bridge Type	Maximum Horizontal Clearance (ft) [a]	Vertical Clearance at Mean High Water (ft) [a]	Condition Ratings[a]	Opened during RM 10.9 Removal Action Barge Operations
Amtrak Dock Bridge	Amtrak	5	Lift	200	24 (138)[b]	N/A	Yes
Bridge Street Bridge	Essex Co.	5.7	Swing	80	7	Deck: Satisfactory Superstructure: Poor Substructure: Satisfactory Condition: Poor Structural Evaluation Appraisal: Minimum tolerable	Yes
Morristown Line RR Bridge	NJ Transit	5.85	Swing	77	15	N/A	Yes
Stickel Bridge	NJDOT	5.9	Lift	200	35 (135)[b]	Deck: Satisfactory Superstructure: Satisfactory Substructure: Satisfactory Condition: Fair	No
Kearny Reach							
Clay Street Bridge	Essex Co.	6.1	Swing	75	7	Deck: Satisfactory Superstructure: Serious Substructure: Fair Condition: Poor Structural Evaluation Appraisal: Intolerable, high priority corrective action	Yes
Fourth Ave Conrail Bridge	Conrail	6.35	Bascule	126	Abandoned in open position	Out of service	No

Table 1. Characteristics and Conditions of Bridges on the Lower Passaic River

Bridge Name	Owner	FNC River Mile	Bridge Type	Maximum Horizontal Clearance (ft) [a]	Vertical Clearance at Mean High Water (ft) [a]	Condition Ratings[a]	Opened during RM 10.9 Removal Action Barge Operations
Arlington Reach							
Erie/Montclair-Greenwood Lake RR Bridge	NJ Transit	8.1	Swing	48	36	Out of service	No
Rutgers (Route 7) Bridge	NJDOT	8.8	Lift	100	8(50) [b]	Deck: Very Good Superstructure: Very Good Substructure: Very Good Condition: Good	Yes
Nutley Reach							
DeJessa-Avondale Street (Kingsland Avenue) Bridge	County Highway Agency	10.6	Open Truss Swing	65	7	Deck: Fair Superstructure: Poor Substructure: Satisfactory Condition: Poor Structural Evaluation Appraisal: Minimum tolerable	Yes
Lyndhurst-Delaware Rail Bridge	NJ Transit	11.7	Swing	47	26	N/A	N/A
Rutherford Reach							
Rutherford Avenue (Route 3) Bridge	NJDOT	11.9	Fixed Span	133	30	Deck: Good Superstructure: Excellent Substructure: Excellent Condition: Good	N/A

Table 1. Characteristics and Conditions of Bridges on the Lower Passaic River

Bridge Name	Owner	FNC River Mile	Bridge Type	Maximum Horizontal Clearance (ft) [a]	Vertical Clearance at Mean High Water (ft) [a]	Condition Ratings[a]	Opened during RM 10.9 Removal Action Barge Operations
Union Avenue Bridge	NA	13.2	Fixed Span	60	16	Deck: Good Superstructure: Very Good Substructure: Good Condition: Good	N/A
Main Avenue/ Gregory Avenue Bridge	NA	14.2	Fixed Truss	71	12	Deck: Good Superstructure: Good Substructure: Satisfactory Condition: Fair	N/A
Wallington Reach							
Market Street/ Wallington Street Bridge	NA	14.7	Fixed Span	100	5	Deck: Good Superstructure: Satisfactory Substructure: Satisfactory Condition: Fair	N/A

Notes:

FNC = federal navigation channel
LPR = Lower Passaic River
NA = not available
N/A = not applicable
NJDOT = New Jersey Department of Transportation
RR = railroad

[a] National Bridge Inventory Database, accessed 5/13/2019 (https://infobridge.fhwa.dot.gov/Data/Map)
[b] Vertical clearance in parentheses refers to clearance when the lift bridge is open.

Table 2. Marine Transportation Contact List

Date(s) of Contact	Name	Company	Reason for Contact
11/10/2014, 11/12/2014	James Morrison	New York Marine Transportation	Piloted tugboat, Specialist II, for RM 10.9 removal action.
11/11/2014	Rudy Sistrunk	Marine Inland Fabricators	President of company responsible for manufacturing low-profile tugboats for Hudson River.
11/18/2014	Bill Hughes	Hughes Marine	An owner of marine transportation company that owns, leases, operates equipment; including barges used for RM 10.9 removal action.
11/18/2014	Andrew Timmis	Cashman Dredging	Contractor involved with the Hudson River remediation.
11/18/2014	Steven Newes	Donjon Marine	Senior vice president of marine transportation company that owns, operates, leases tugboats and barges in greater NY-NJ-PA area. Has working knowledge of LPR.
11/11/2014, 11/20/2014	Sven Van Batavia	Miller's Launch	Project manager for marine transportation company that owns, operates, leases tugboats and barges in greater NY-NJ-PA area. Provided vessel support for past LPR investigation work.
11/25/2014, 12/5/2014	Gerard Harold (GH) Magee III	Greater NY Marine (formerly employed by NY Marine Transportation)	In prior employment, piloted tugboat, with James Morrison, for the RM 10.9 removal.
1/22/15	Andrew Inglis	GE	Leader of dredging operations, GE Hudson River Project

Table 3. RM 10.9 Removal Action Equipment

Type	Description
Tugboats	
Specialist	2,400 hp, twin screw, Vertical clearance: 35 ft with pilot house in raised position; 25 ft with pilot house in lowered position and wheelhouse in raised position; 17 ft with wheelhouse in lowered position
Eastern Dawn	2,400 hp, twin screw
Mister Jim	1,300 hp
Harbor II	450 hp, twin screw (equipment movement support)
Captain Zeke	*No information found*
Dory	1,600 hp, twin screw
Barges	
Former City of New York Department of Sanitation	150 ft long by 37 ft wide At 10 ft draft, carries 1,100 tons
DMT 3235 and DMT 3236	150 ft long by 40 ft wide Maximum draft 17.5 ft 3,000 cy
Chubby and Stymie	*No information found*

Notes: Information and specifications provided as available. Information sources consisted of interviews, the RM 10.9 Final Construction Report (CH2M Hill 2019) and internet searches, and were verified to the extent possible.

APPENDIX F
CONCEPTUAL CAP DESIGN EVALUATION

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

Prepared for
Lower Passaic River Cooperating Parties Group
New Jersey

Prepared by

integral consulting inc.

September 2021

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
cfs	cubic feet per second
FS	feasibility study
IR	interim remedy
LPR	Lower Passaic River
LPRSA	Lower Passaic River Study Area
PCB	polychlorinated biphenyl
PCB-52	2,5,2′,5′-tetrachlorobiphenyl
RI	Remedial Investigation
RM	river mile

1 INTRODUCTION

This appendix presents a summary of the evaluation completed to develop a conceptual cap design to support the comparative evaluation of remedial alternatives in the upper 9-mile source control interim remedy (IR) feasibility study (FS) for the Lower Passaic River Study Area (LPRSA). This evaluation was completed based on data presented in the LPRSA Remedial Investigation (RI) Report (AQEA 2019) and assumptions and methods developed for the River Mile (RM) 10.9 cap design (CH2M Hill 2013a,b,c). Cap composition was evaluated to determine basic requirements for isolating underlying sediment and limiting contaminant migration.

2 CONCEPTUAL CAP DESIGN

The placement of engineered caps is a common element to each of the active remedial alternatives presented in the IR FS. The conceptual design evaluation presented in the following sections was completed to provide the supporting basis for the conceptual cap assumptions used in the IR FS.

2.1 DESIGN OBJECTIVES

The primary objective of the proposed cap is to isolate and limit migration of contaminants from underlying sediments to the bioactive sediment layer and water column. For this preliminary, feasibility-level evaluation, chemical isolation of polychlorinated biphenyls (PCBs) and dioxins/furans was evaluated for a 100-year time frame. A 100-year cap modeling period for a preliminary performance evaluation was established consistent with the Treatability Study Work Plan for the Lower 8.3 Miles of the Lower Passaic River (Arcadis 2018). Extending the model duration will be evaluated during the design phase. Chemical breakthrough conditions are defined as porewater concentrations at the surface of the cap isolation layer exceeding the New Jersey surface water quality standard criterion for total PCBs and 2,3,7,8-tetrachloro-dibenzo-*p*-dioxin (2,3,7,8-TCDD), of 6.4×10^{-5} µg/L and 5×10^{-9} µg/L, respectively (CH2M Hill 2013c). The time of breakthrough is dependent on the sediment, isolation layer properties, and overlying water physical, chemical, and biological conditions outlined in Section 2.2.

An additional objective of the proposed cap is to provide physical containment of underlying sediments. To maintain its physical integrity, an armor layer is typically required to prevent erosion of the cap material under river flows or other erosive forces. Armoring requirements were evaluated using a 100-year return period flow, consistent with the RM 10.9 remedial design and USEPA (2005) guidance.

2.2 CHEMICAL CONTAINMENT MODELING

The numerical cap model CapSim 3.7 (Reible Research Group 2019) was used to determine a cap configuration that would provide effective chemical containment. Cap model parameters were based on the RM 10.9 cap design. The general cap section used for the model includes the native underlying sediment layer, a chemical containment layer, and an upper layer to provide bioturbation/habitat substrate and/or armoring. The primary chemicals of concern are PCBs and 2,3,7,8-TCDD. The representative chemical constituent used for modeling PCBs was 2,5,2′,5′-tetrachlorobiphenyl (PCB-52), selected on the basis of its higher mobility relative to other PCBs, resulting in a more conservative model of cap breakthrough times (CH2M Hill 2013c). Additional constituents will be modeled for cap breakthrough during the design phase.

2.2.1 Underlying Sediment

Physical and chemical characteristics for model input parameters describing the underlying sediment based on the assumed dredge depth (i.e., 2.5 to 3.5 ft) layer were determined on the basis of the RM 10.9 cap model and data summarized for the RI Report (AQEA 2019). As a conservative estimate for contaminant concentrations within the underlying sediment, the maximum concentrations presented in the RI Report for PCB-52 and 2,3,7,8-TCDD within the sediment of the upper 9 miles of the Lower Passaic River (LPR) were applied in the model. Maximum underlying sediment concentrations by reach were converted to porewater concentrations using the fraction of organic carbon in the sediment and the distribution coefficient for PCB-52 and 2,3,7,8-TCDD (Table 1). The maximum porewater concentrations determined for the upper 9 miles were applied in the model for this preliminary performance evaluation. Concentrations specific to each reach may be considered for modeling during the design phase. Physical and chemical input parameters including groundwater seepage velocity were based on the RM 10.9 design and are summarized in Tables 2–6 (CH2M Hill 2013a,b,c).

2.2.2 Cap Isolation Layer

The isolation layer was developed using model input parameters for physical and chemical characteristics of cap material adapted from the RM 10.9 remedial design. The isolation layer evaluated consists of a 1 ft layer containing varying weight fractions of sand and carbon content. The thickness of the active cap layer is based on the average cap thickness determined for the RM 10.9 remedial design that would prevent breakthrough over the course of the model time period. The required fraction of carbon was determined on the basis of the time of breakthrough of underlying sediment PCB-52 and 2,3,7,8-TCDD constituents over the course of the modeled time frame.

2.2.3 Bioturbation Layer

The bioturbation layer is typically a sand layer, with possible fines or additional substrate, applied on top of the cap isolation layer to provide habitat for benthic organisms. Based on data collected as a part of the Lower Eight Miles of the Lower Passaic River Risk Assessment (Appendix D of Lower Eight Miles of Lower Passaic Focused Feasibility Study Report; Louis Berger 2014), the biologically active zone for the lower 8 miles of the LPRSA averaged between 13.7 and 16.4 cm. As modeled in the RM 10.9 remedial design, a layer for bioturbation of 30.5 cm (1 ft) was applied, which is approximately twice the depth of the biologically active zone, allowing for additional protection between the isolation layer and the biologically active zone.

The final composition of the layer placed on top of the isolation layer will be evaluated for each area during remedial design, such as applying armor vs. habitat reconstruction material for bioturbation along channels vs. mudflats. As stated previously, the primary objective of the cap

is to prevent contaminant breakthrough of the isolation layer, and this upper layer is not anticipated to have much or any impact on breakthrough times. Cap modeling excluding the bioturbation layer may be conducted during the design phase to more conservatively predict breakthrough at the isolation layer.

2.3 ARMOR

Following the cap isolation layer, application of a bioturbation layer consisting of habitat reconstruction material in areas such as mudflats and shoals, or armor layer applied in channels, or a combination of bioturbation material and armor will be determined during the final design phase. Bioturbation and armor placement requirements will be determined in the design phase. Based on the assumptions made in the U.S. Environmental Protection Agency's 2014 Focused Feasibility Study (Louis Berger 2014), erosive forces having the most impact on the armor layer will result from flood flows, while vessel traffic, including propeller wash and boat wake will have little impact. For the purpose of supporting the IR FS, the conceptual model evaluated armor size based on the flood flow. During the design phase, the armor layer will be designed for impacts due to wind and vessel-generated waves, propeller wash, and flood flows specific to the cap placement areas. For areas requiring armor, such as the channels, the size and thickness of the armor for the upper 9 miles of the LPR was determined on the basis of the 100-year return period flood, which is consistent with recommendations in USEPA (2005) guidance. The predicted flow rate for 100-year event based on the flow record is roughly 22,000 cubic feet per second (cfs) at the U.S. Geological Survey Little Falls gauge station (AQEA 2019). Depth averaged velocities throughout the LPRSA range from 0.3 to 9.3 ft per second (Moffat & Nichol 2014). For a conservative estimate of armor size, the maximum average velocity was used to calculate armor depths. Based on the maximum average depth-averaged velocity and associated depths, a characteristic armor size (D_{50}) of approximately 6 in. was calculated, resulting in an armor thickness of about 1 ft. Required armor thickness is typically determined as 1.5 times the characteristic armor size. When placing the armor material underwater, the thickness of the armor should be increased by 50 percent due to a reduced ability to ensure even placement of stone. For purposes of this conceptual design, the minimum thickness of the armor layer is therefore assumed to be 2.25 times the D_{50} (Maynord 1998). Final armor thicknesses and appropriate stability coefficients will be determined during the design phase. Based on the 100-year return period flow, an armor layer approximately 13.8 in. thick with a D_{50} of about 6 in. is required. With the following equation (Palermo et al. 1998), the characteristic armor size (D_{50}) and the required depth of armor layer were calculated:

$$D_{50} = S_f C_s C_v C_T C_G d \left[\left(\frac{\tilde{a}_w}{\tilde{a}_s - \tilde{a}_w} \right)^{1/2} \frac{V}{\sqrt{K_1 g d}} \right]^{2.5}$$

Where:

D_{50}	=	Characteristic stone size of which 50 percent is finer
S_f	=	Safety factor, minimum of 1.1
		Safety factor of 1.1 used for this calculation with conservative velocity input.
C_s	=	Stability coefficient for incipient failure (0.3 for angular rock, 0.375 for rounded rock).
		Calculated for angular rock, assuming rounded rock increases stone size requirements.
C_v	=	Vertical velocity coefficient (1.0 for straight channels and inside of bends; 1.283-0.2log(R/W) for outside of bends)
		Coefficient of 1.0 used for calculation as in the RM 10.9 design. Evaluation of coefficient will be considered during design phase.
C_T	=	Thickness coefficient = 1.0 if thickness = D_{100}(max) or 1.5D_{50}(max)
		For this calculation, a thickness coefficient of 1.0 was used as in the RM 10.9 design.
C_G	=	Gradation coefficient = $(D_{85}/D_{15})^{1/3}$
D_{85}/D_{15}	=	Gradation uniformity coefficient (typical range 1.8 to 3.5)
		For this analysis, coefficient of 3.5 was used to account for angular rock.
d	=	Local water depth
		The local water depth was estimated to be approximately 10 ft in areas where high average velocity profiles were observed.
$\tilde{a}_w$	=	Unit weight of water (assumed 62.4 lb/ft^2)
$\tilde{a}_s$	=	Unit weight of stone (assumed 165 lb/ft^2)
V	=	Local depth-averaged velocity
		For a conservative estimate, the maximum of the depth average velocities was applied (9.3 fps).
K_1	=	Side slope correction factor.
K_1	=	$\sqrt{1-\frac{sin^2\theta}{sin^2\varphi}}$
θ	=	Bottom slope angle
φ	=	Angle of repose
		A side slope correction factor (K_1) of 1.0 corresponds to a flat bottom. A slope ratio of 4:1 (H:D) was assumed with a 40 degree angle of

repose, resulting in a K_1 equal to 0.93 based on slope correction factor applied in the RM 10.9 design. Slope angles corresponding the upper 9 miles of the LPRSA will be assessed during the design phase.

g = Acceleration due to gravity (32.2 ft/s^2)

3 CAP MODEL RESULTS

The required carbon content of the cap isolation layer was evaluated to determine the necessary composition to isolate and limit migration of PCB-52 and 2,3,7,8-TCDD in underlying sediment over the course of the modeled time frame. Model inputs described in Tables 2–6 were developed using data from previous studies and implemented designs in the LPRSA. These characteristics, assumptions, and model input parameters were applied to develop a preliminary, feasibility-level evaluation.

To establish minimum cap requirements, an isolation layer consisting of sand with a carbon fraction (f_{oc}) ranging from 0.001 to 0.01 was evaluated to determine if sand would be effective at isolating underlying sediment and limiting contaminant migration. The model results indicate that an isolation layer containing 0.1 percent carbon would not prevent migration of 2,3,7,8-TCDD, and breakthrough was predicted above the isolation layer (Figure 1) during the 100-year model period. An isolation layer with a carbon content of 1 percent was predicted to prevent breakthrough of 2,3,7,8-TCDD during the 100-year period (Figure 1). Migration of 2,3,7,8-TCDD with concentrations exceeding the threshold of 5×10^{-9} µg/L was predicted at about 6 in. into the 1 ft cap.

When assessing carbon requirements for isolating PCB-52, an isolation layer consisting of sand with a carbon content of 1 percent did not prevent breakthrough within the 100-year period (Figure 2). An isolation layer composed of sand with an elevated organic carbon content was evaluated to determine the amount of the carbon required to limit migration of PCB-52. The model results indicate that a minimum carbon content of 5 percent is required to prevent breakthrough of PCB-52 over the course of the 100-year model period (Figure 2). Migration of PCB-52 with concentrations exceeding the threshold of 6.4×10^{-5} µg/L was predicted at about 8 in. into the 1 ft cap.

An additional evaluation was completed to determine the amount of activated carbon that would be required to prevent migration. The isolation layer evaluated was composed of a mixture of sand with activated carbon. A minimum of 0.5 percent total organic carbon, provided by activated carbon amendment, was required in the model to prevent breakthrough of contaminants through the isolation layer over the 100-year model period (Figure 3).

4 CONCEPTUAL CAP CONFIGURATION

Sediment cap composition and armor requirements were evaluated on the basis of physical and chemical conditions of the upper 9-miles of the LPR and general characteristics of the LPRSA provided by previous studies. The completed evaluation is a preliminary assessment to determine basic cap composition requirements. Based on the evaluation and model results, an isolation layer consisting of only sand will not prevent breakthrough of underlying sediment contaminants to surface material. A 1 ft thick isolation layer will require an additional carbon amendment provided by a carbon substrate or activated carbon. Based on the preliminary evaluation, a 1 ft thick isolation layer with elevated carbon content, and a 1 ft armor layer would be required to isolate underlying sediment and maintain cap stability during a 100-year return period flow. The cap configuration is shown (Figure 4).

During the design phase, additional parameters will be evaluated including required cap amendments to isolate and limit migration of underlying sediment contaminants over the course of a longer time frame. Additional contaminants will be evaluated, such as metals and polycyclic aromatic hydrocarbons, depending on underlying sediment contaminant concentrations. Different cap compositions will be dependent on areas of placement, such as sediment containing different levels of contamination, and located in areas including the mudflats or deep channels. Cap model input parameters will be updated when additional data are collected for the upper 9-mile area.

5 REFERENCES

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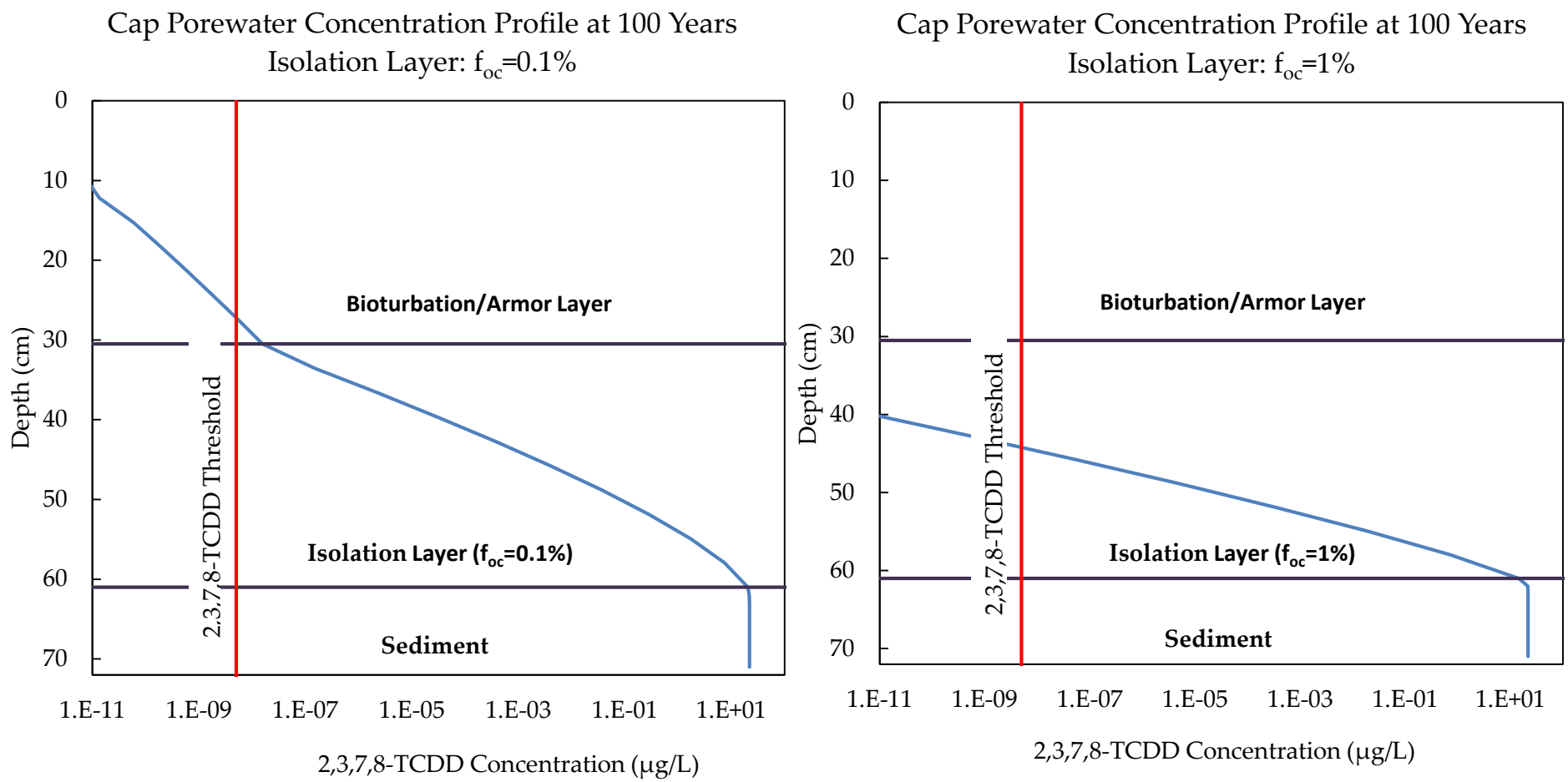
Figures



Note:
Cap isolation layer consists of sand
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
f_{oc} = carbon content fraction

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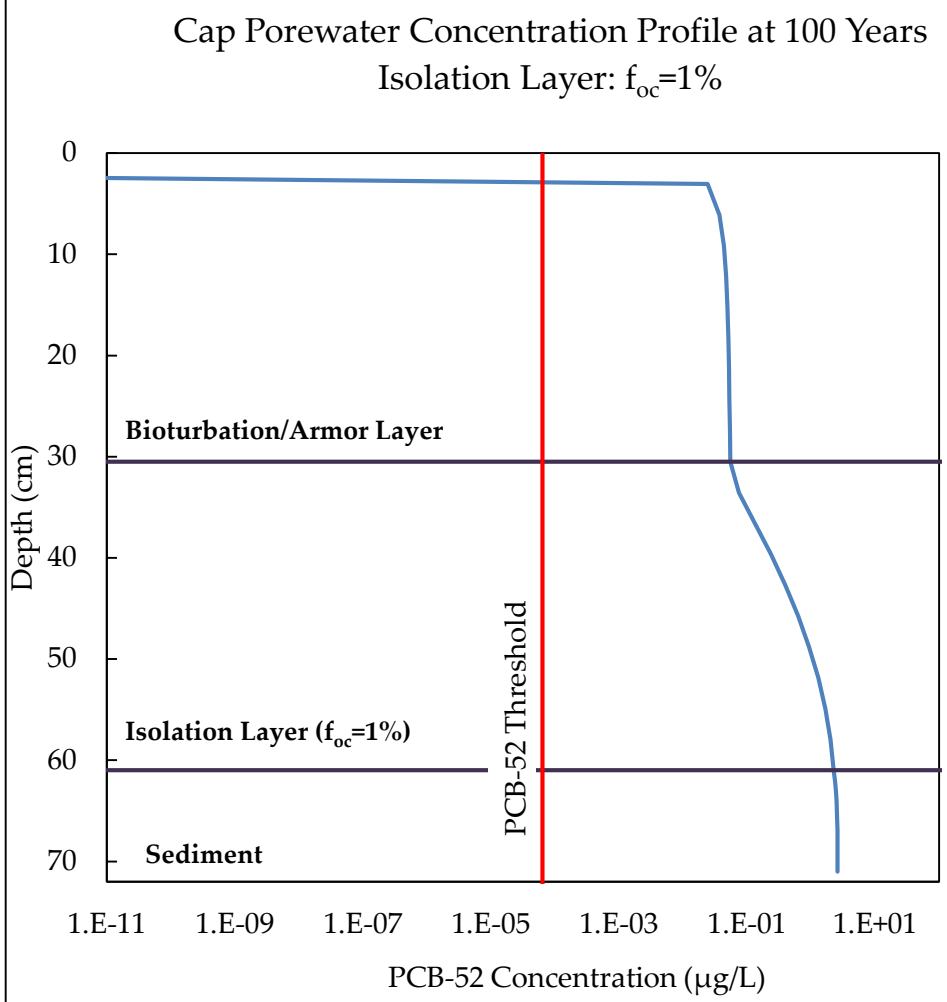
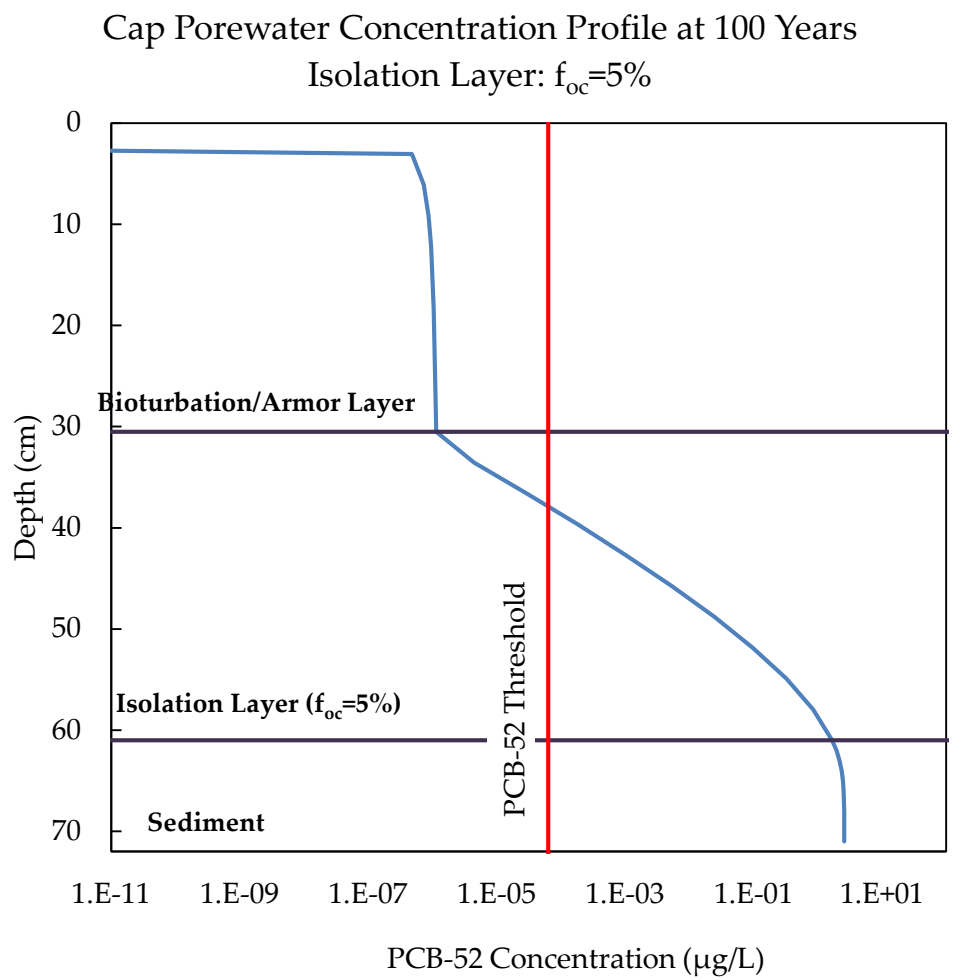
Figure 1.
2,3,7,8-TCDD Concentration Profile across Cap Layers
Cap Isolation Layer = Sand





Note:
Cap isolation layer consists of sand
PCB-52 = 2,5,2′,5′-tetrachlorobiphenyl
f_{oc} = carbon content fraction

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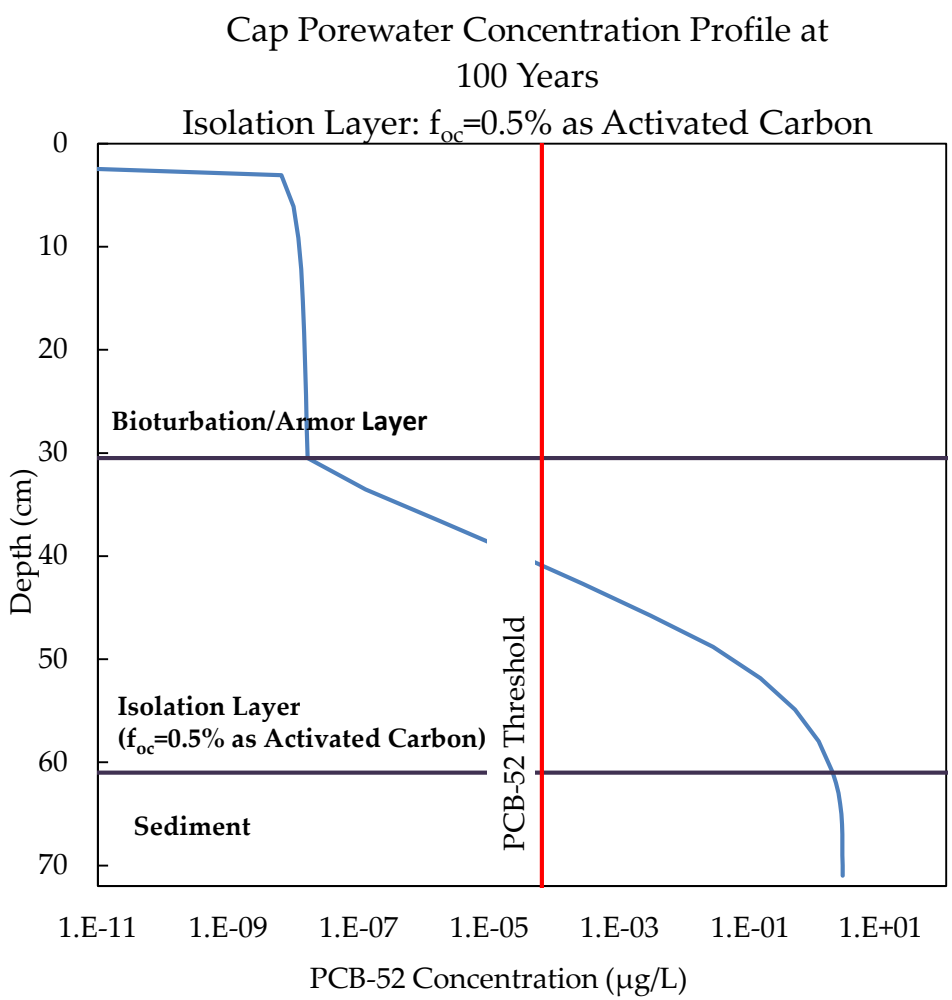
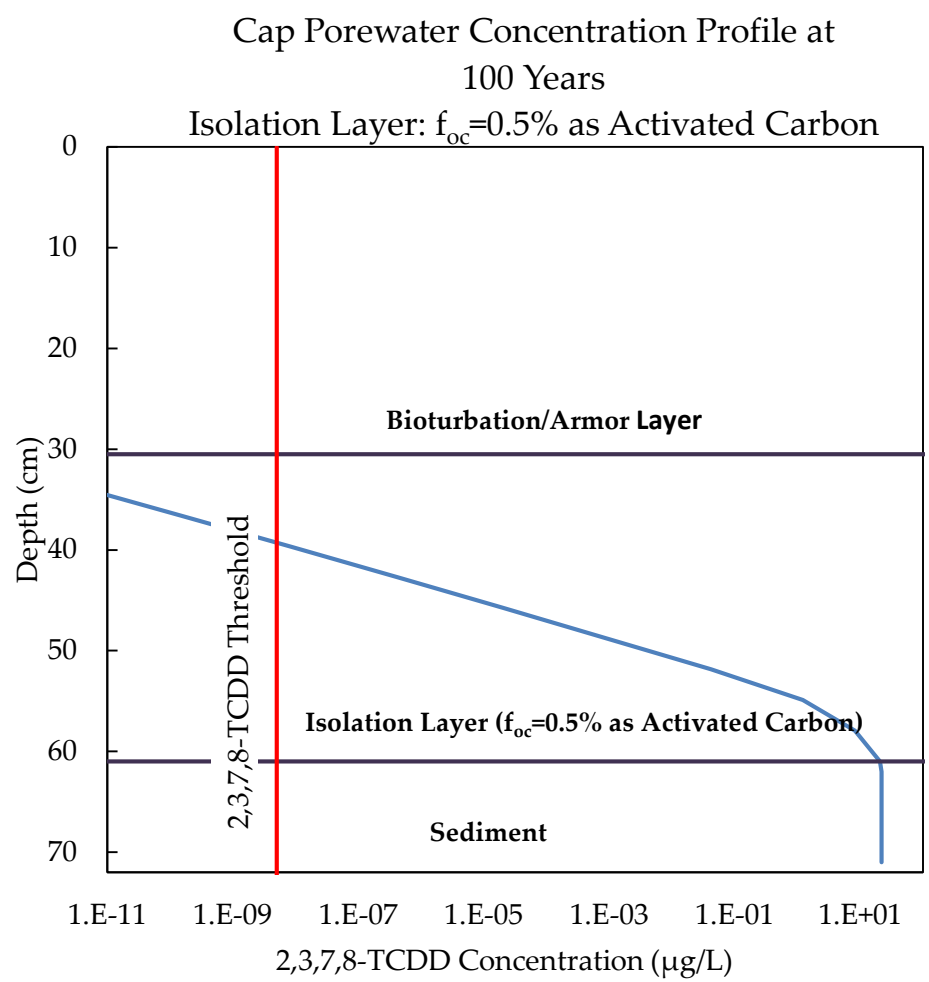
Figure 2.
PCB-52 Concentration Profile across Cap Layers
Cap Isolation Layer = Sand





Note:
Cap isolation layer consists of sand with activated carbon
PCB-52 = 2,5,2′,5′-tetrachlorobiphenyl
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
f_{oc} = carbon content fraction

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Figure 3.
PCB-52 and 2,3,7,8-TCDD Concentration Profile across Cap Layers
Isolation Layer = Sand with Activated Carbon

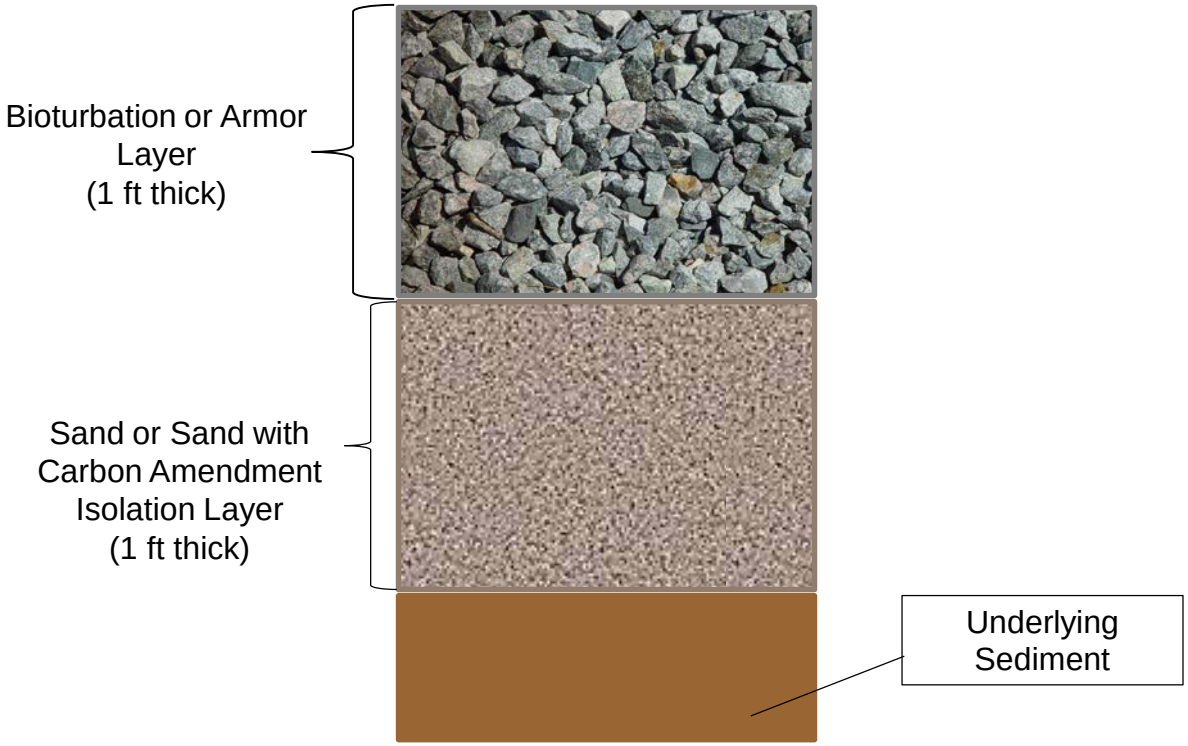

Figure 4.
Preliminary Cap Configuration

Tables

Table 1. Underlying Sediment Concentrations (depth of 2.5–3.5 ft)

	River Mile				
Constituent	7.8–9.2	9.2–10.4	10.4–11.2	11.2–12.5	12.5–14
Sediment Concentration (mg/kg)					
PCB-52	7.2	1.8	29	1.2	34
2,3,7,8-TCDD	2,585	2,547	29,800	5,720	9,390
Porewater Concentration (µg/L)					
PCB-52	0.55	0.14	2.21	0.09	**2.59**
2,3,7,8-TCDD	1.89	1.86	**21.75**	4.18	6.85

Notes:

Bold = Maximum porewater concentration applied in cap evaluation**.**

Maximum concentrations measured in underlying sediments at depths expected to be exposed following dredging (2.5–3.5 ft).

Sediment concentrations reported as a part of the 2019 remedial investigation (AQEA 2019).

Sediment concentrations converted to porewater concentrations using organic carbon partitioning coefficients, Log(Koc), of 5.37 L/kg and 7.39 L/kg for PCB-52 and 2,3,7,8-TCDD, respectively. Coefficients and sediment organic carbon fraction (0.056) based on RM 10.9 design.

Table 2. Chemical Properties

Chemical	MW (g/mol) [a]	T (°C)	Dw (cm^2/s) [b]	K_{OC} [log(L/kg)] [b]	K_{DOC} [log(L/kg)][b]
PCB-52	292	25	5.04E-06	5.37	5.52
2,3,7,8-TCDD	322	25	4.73E-06	7.39	6.38

Notes:

Dw = molecular diffusivity in water

K_{DOC} = organic carbon partition coefficient

K_{OC} = organic carbon partition coefficient

MW = molecular weight

T = temperature

References:

[a] NIH. 2020. Pubchem Compound Summary. https://pubchem.ncbi.nlm.nih.gov/. Accessed on January 20, 2020. National Institutes of Health, U.S. National Library of Medicine, and National Center for Biotechnology Information.

[b] CH2M HILL. 2013b. CapSim Version 2.6 Model Input Parameters Supporting the Design of the River Mile (RM) 10.3 Engineered Sediment Cap. (May 10)

Table 3. Cap Layer Composition Evaluated for 100 Years

Layer	Weight Fraction	Porosity	Bulk Density (g/cm^2)	f_{oc}	Tortuosity Correction	Thickness (cm)	Hydrodynamic Dispersivity (cm)	DOC (mg/L)
Cap Configuration Evaluation 1 [Isolation Layer = Sand, TOC = 1%]—Prevents Breakthrough of 2,3,7,8-TCDD								
Bioturbation/ Armor	1	0.4	1.6	0	Millington & Quirk	30.5	2.8	0
Isolation Layer								
Sand	1	0.4	1.6	0.01	Millington & Quirk	30.5	2.8	0
Sediment	1	0.65	1.6	0.056	Boudreau	20	2.8	0
Cap Configuration Evaluation 2 [Isolation Layer = Sand with TOC = 5%]—Prevents Breakthrough of PCB-52								
Bioturbation/ Armor	1	0.4	1.6	0	Millington & Quirk	30.5	2.8	0
Isolation Layer								
Sand	1	0.4	1.6	0.05	Millington & Quirk	30.5	2.8	0
Sediment	1	0.65	1.6	0.056	Boudreau	20	2.8	0
Cap Configuration Evaluation 3 [Isolation Layer = Sand + Activated Carbon (0.5%)]—Prevents Breakthrough of 2,3,7,8-TCDD and PCB-52								
Bioturbation/ Armor	1	0.4	1.6	0	Millington & Quirk	30.5	2.8	0
Isolation Layer								
AC	0.005	0.6	0.4	1				
Sand	0.995	0.4	1.6	0.001				
Total	1	0.404	1.5764	0.005	Millington & Quirk	30.5	2.8	0
Sediment	1	0.65	1.6	0.056	Boudreau	20	2.8	0

Notes:

AC = activated carbon
DOC = dissolved organic carbon
foc = organic carbon fraction

Table 4. Sorption Isotherms

Matrix, Chemical	Sorption Isotherm	Sorption Isotherm Coefficient		Isotherm Coefficient	
PCB-52					
Sand	Linear -- Kocfoc	Kd (L/kg)	2.34E+01		
Activated Carbon	Freundlich (q=KfCN)	Kf (µg/kg/(µg/L)$^{1/n}$	1.78E+06	N	0.86
Sediment	Linear -- Kocfoc	Kd (L/kg)	1.31E+04	foc	0.056
Sediment	Linear -- Kocfoc	Log(Koc)	5.37	foc	0.056
2,3,7,8-TCDD					
Sand	Linear -- Kocfoc	Kd (L/kg)	2.46E+03		
Activated Carbon	Freundlich (q=KfCN)	Kf (µg/kg/(µg/L)$^{1/n}$	7.94E+06	N	0.68
Sediment	Linear -- Kocfoc	Kd (L/kg)	1.38E+06	foc	0.056
Sediment	Linear -- Kocfoc	Log Koc	7.39	foc	0.056

Notes:

Koc = organic carbon sorption constant

foc = fraction of organic carbon

q, Kf, N = Freundlich isotherm constants

Reference:

CH2M HILL. 2013b. CapSim Version 2.6 Model Input Parameters Supporting the Design of the River Mile (RM) 10.3 Engineered Sediment Cap. (May 10)

Table 5. System Properties

Upwelling Groundwater Flow		Modeling Bioturbation		Modeling Consolidation	
Steady Flow		Uniform		Consolidation	
Darcy Velocity (cm/yr)	314	Bioturbation depth (cm)	15	Maximum consolidation depth (cm)	23
		Particle biodiffusion coefficient (cm^2/yr)	1	Time to 90% consolidation (yr)	1
		Porewater biodiffusion coefficient (cm^2/yr)	100		

Table 6. Auxiliary Conditions—Input Boundary Conditions and Initial Concentration Profiles (µg/L)

Chemical	Benthic Layer [Fixed]	Layer 1 [Uniform]	Layer 2 [Uniform]	Layer 3 [Uniform]	Underlying Layer [Fixed]
PCB-52	0	0	0	2.59	2.59
2,3,7,8-TCDD	0	0	0	21.75	21.75

APPENDIX G
COST ESTIMATES

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

Prepared for
Lower Passaic River Cooperating Parties Group
New Jersey

Prepared by
integral consulting inc.

September 2021

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ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
EPA	U.S. Environmental Protection Agency
FS	feasibility study
IR	interim remedy
LPR	Lower Passaic River
OMM	operation, maintenance, and monitoring
PCB	polychlorinated biphenyl
PDI	pre-design investigation
RAL	remedial action level
RM	river mile
ROD	record of decision
SWAC	surface area-weighted average concentration

1 INTRODUCTION

This appendix presents the detailed cost estimates for the five remedial alternatives presented in the Upper 9-Mile Source Control Interim Remedy (IR) Feasibility Study (FS) for the Lower Passaic River (LPR) Study Area. The five alternatives are:

- Alternative 1: No action
- Alternative 2: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 85 ng/kg and PCB RAL of 1 mg/kg
- Alternative 3: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 75 ng/kg and PCB RAL of 1 mg/kg
- Alternative 4: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 65 ng/kg and PCB RAL of 1 mg/kg
- Alternative 5: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 125 ng/kg.

The following information is provided in this appendix:

- Basis of estimates, presenting key cost estimate assumptions
- Cost estimate summary
- Cost estimate uncertainties.

The cost estimates presented herein are considered suitable for comparative purposes in the FS and in planning only. The accuracy of these estimates is considered to be +50 percent/–30 percent, consistent with the U.S. Environmental Protection Agency's (EPA's) *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study* (USEPA 2000). The expected level of accuracy is a function of the level of engineering upon which the cost estimate is based. In the FS, remedial alternatives are defined and analyzed at the conceptual design level only. The expected level of accuracy will increase as additional engineering (e.g., completion of preliminary design or final design) and procurement are completed. As a result, the final project costs will vary from the cost estimates presented herein.

2 BASIS OF ESTIMATES

Design assumptions and quantities are presented in Appendix A.

Key cost estimate assumptions are:

- Direct capital costs are primarily built up based on FS quantities and unit costs from prior projects and published sources, such as RS Means cost database (RSMeans Data Online).
- Some costs have been additionally based on communication with vendors.
- All capital costs based on prior projects have been adjusted to account for inflation.
- Where possible, costs are local to Newark, New Jersey.
- Current Conditions sampling is not included.
- Pre-design investigation (PDI) cost is approximate and estimated based on:
  - Sediment cores on 80-ft centers (1,900 locations, 4 segments/core)
  - Approximately 20 percent additional locations for footprint refinement
  - Full analyte suite, geotechnical analyses, quality assurance samples, and data validation
  - Bathymetry survey
  - Debris identification survey
  - Supporting surveys (e.g., habitat, cultural and fish spawning).
- PDI elements and costs will be refined during remedial design and following completion of Current Conditions sampling.
- Remedial design cost includes update and refinement of the numerical models.
- PDI and remedial design are lump sum costs that do not vary with the alternatives.
- Indirect capital costs (aside from PDI and remedial design) scale with the scope and duration of the remedial alternatives and are based on appropriate factors (percentages) applied to the direct capital plus contingency costs, based on professional judgment and EPA guidance (USEPA 2000).
- Dredging and capping unit costs are based on actual costs from LPR RM 10.9 removal action (CH2M Hill 2019), LPR Phase 1 removal action (Tierra 2013), and other similar sediment remediation projects that involved dredging and capping.
- Upland site staging area costs are based on regional real estate costs for a vacant, uncontaminated property. Property will be used for contractor trailers, sample processing, equipment storage, and parking. The cost estimate assumes the parcel used

for the staging area will be in a condition that permits immediate installation of support facilities. The cost estimate does not include provisions for additional site preparation or cleanup (demolition, abatement, or other cleanup activities).

- The sediment processing unit cost is based on vendor communication, considering the commercial processing facility cost of the LPR RM 10.9 removal action (CH2M Hill 2019), which used Clean Earth. Barge dewatering will precede transfer of sediment to the commercial processing facility, and is included in the sediment processing cost.
- The transportation and disposal unit costs are based on vendor communication and the LPR RM 10.9 removal action (CH2M Hill 2019), as treatment and disposal of sediment in the upper 9 miles is assumed to be similar to the RM 10.9 removal action. Transportation and treatment of effluent water from barges is included in transportation and disposal cost.
- External costs to be borne by others (e.g., bridge maintenance and repairs) are not included.
- Costs for annual operation, maintenance, and monitoring (OMM) are assumed to begin in Year 5 (at the completion of construction), in keeping with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) 5-year review requirements, and extend for 30 years after construction is complete.[1]
- Periodic costs are assumed to begin in Year 5 (at the completion of construction), in keeping with CERCLA 5-year review requirements, and extend for 30 years after construction is complete.[1] Periodic costs include:
  - Fourteen long-term monitoring events, which include surface water and biota sampling.[1]
    - Surface water sampling includes physical and small volume chemical water column monitoring and is based on the scope of the Current Conditions program. The scope will be reevaluated during remedial design following review of Current Conditions results.
    - Biota sampling includes the collection of small forage fish and two other species and a sediment profile imaging survey. Compositing and level of effort by reach will be established during the PDI following review of the Current Conditions results.
    - The scope of the long-term monitoring is assumed to be the same for all active alternatives.
  - Seven cap monitoring events, where cost varies by remedial footprint area

[1] Issuance of a final ROD would replace the monitoring and maintenance requirements of the IR.

  - Six bathymetric survey events, where the scope is assumed to be the same for all active alternatives.
  - One initial post-IR completion surface sediment sampling event, consisting of 400 locations. Costs are based on a full analytical suite, quality assurance samples, data validation, equipment, facilities, labor, and expenses. The scope is assumed to be the same for all active alternatives.
  - Six potential additional surface sediment sampling events, consisting of 200 locations each, otherwise based on the same assumptions as the initial sediment sampling event.
- Cost estimates include direct capital and OMM contingency of 25 percent (15 percent of scope contingency and 10 percent of bid contingency).
- Present worth values of capital costs incurred after Year 0 and annual OMM costs are based on application of a 7 percent discount rate, per EPA guidance (USEPA 2000).

3 COST ESTIMATE SUMMARY

Costs are presented in the following tables:

- Tables G-1a through G-4i present detailed cost estimates and cost backup sheets for the four active alternatives.
- Table G-5 presents the overall summary of the cost estimates.
- Table G-6 presents a sensitivity analysis of discount rate and contingency factor.
- Table G-7 presents a cost comparison of disposal in a Subtitle D versus a Subtitle C landfill.
- Table G-8 presents the dredging technology cost sensitivity evaluation summary (which is discussed in Attachment G1).

4 COST ESTIMATE UNCERTAINTY

Significant cost uncertainties exist at the FS level and are addressed through contingencies. The upper 9-mile IR FS cost estimate has significant scope and bid uncertainties due to the scope and scale of the project and the conceptual level of engineering analysis performed at the FS stage of a remediation projection—hence the selection and use of the 25 percent contingency factor.

Factors that may alter the project cost due to uncertainties in the ultimate project scope (scope contingency) are:

- Remedy approach changes in the ROD or remedial design[2]
- Area of the final remedial footprint needed to achieve remedial action objectives
- Dredging depth (including overdredge allowance) needed to accommodate final cap design
- Selection of dredged material transportation options and landfill type.[3]
- Extent of OMM activities (e.g., sample collection, cap maintenance)
- Additional regulatory requirements.

Specific uncertainties related to the cost of constructing or implementing a project with a given scope (bid contingency) may include:

- Unforeseen dredging challenges (hardpan, debris, utilities, etc.)
- Major delays due to external factors (e.g., bridge failure, storm events)
- Changes in regulatory requirements during the project
- Market condition variations that affect pricing of goods and services.

The contingency factor of 25 percent applied to the cost estimates in this FS is intended to capture the potential impact of these uncertainties on future remedy implementation costs to a reasonable degree. Taking into account the significant uncertainties that surround remedial actions on a site as complex as the LPR, the possibility exists that actual costs may be substantially higher than the estimates developed for the FS. As stated previously, the FS cost estimates are considered to represent a +50/–30 percent level of accuracy. Major changes in the

[2] Cost sensitivity to dredging technology is evaluated in Attachment G1 and summarized in Table G-8.
[3] Cost sensitivity to landfill type (i.e., Subtitle C or Subtitle D) is presented in Table G-7.

scope, timing, and implementation of remedial action on the LPR may result in cost impacts that are outside of this range.

A sensitivity analysis, varying both the contingency factor and the discount rate, was performed for each alternative (Table G-6). Contingency was varied from 25 to 35 percent. The discount rate was varied from 7 percent, down to 1.5 percent, per the U.S. Office of Management and Budget's *Circular A-94 Guideline and Discount Rates for Benefit-Cost Analysis of Federal Programs* real interest rates for a 30-year time period (OMB 2018). For comparison purposes, the undiscounted cost was also included in the sensitivity analysis for each alternative.

5 REFERENCES

CH2M Hill. 2019. River mile 10.9 removal action final construction report, Lower Passaic River Study Area. Prepared for the Lower Passaic River Cooperating Parties Group, August. CH2M Hill, Inc., Dayton, OH.

OMB. 2018. Circular A-94. Guideline and discount rates for benefit-cost analysis of federal programs. U.S. Government, Office of Management and Budget, Washington, DC. November.

Tierra. 2013. Final construction report Lower Passaic River Study Area Phase I removal action, March. Tierra Solutions, Inc., East Brunswick, NJ.

USEPA. 2000. A guide to developing and documenting cost estimates during the feasibility study. U.S. Environmental Protection Agency, Washington, DC.

USEPA. 2016. Lower eight miles of the Lower Passaic River, part of the Diamond Alkali Superfund site, Essex and Hudson Counties, New Jersey. Superfund Record of Decision. U.S. Environmental Protection Agency Region 2, New York, NY.

Tables

Table G-1a. Alternative 2 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
KEY ASSUMPTIONS				
Contingency[b]	%	25		
Discount rate, i[c]	%	7.0		
DIRECT CAPITAL COSTS[d]				
Construction Staging Facility				
Staging Area Land Purchase/Lease	AC	5	$ 200,000	$ 1,000,000
Support Facilities	YR	4	$ 310,000	$ 1,300,000
Subtotal Construction Staging Facility				**$ 2,300,000**
Dredging				
Mobilization/Demobilization[e]	LS	1	$ 1,320,400	$ 1,300,000
Protections & Controls	LS	1	$ 1,420,000	$ 1,400,000
Mechanical Dredging[f]	CY	363,069	$ 69	$ 25,200,000
Debris Removal	DY	585	$ 3,880	$ 2,300,000
Bathymetric Verification Survey	DY	663	$ 5,600	$ 3,700,000
Water Quality Monitoring	DY	663	$ 11,000	$ 7,300,000
Additional Construction Performance Monitoring	YR	5	$ 1,000,000	$ 5,000,000
Monitoring Reporting	YR	5	$ 150,000	$ 800,000
Barge Unloading/Material Handling	CY	363,069	$ 15	$ 5,400,000
Subtotal Dredging				**$ 52,400,000**
Capping				
Mobilization/Demobilization[e]	LS	1	$ 902,800	$ 900,000
Material Purchase & Delivery[g]	CY	363,069	$ 40	$ 14,400,000
On-Site Material Handling & Placement	CY	363,069	$ 50	$ 18,200,000
Residual Management	LS	1	$ 1,160,100	$ 1,200,000
Subtotal Capping				**$ 34,700,000**
Dredged Material Processing				
Sediment Processing at Commercial Facility	CY	363,069	$ 160	$ 58,100,000
Subtotal Dredged Material Processing				**$ 58,100,000**
Transportation & Disposal				
Transportation & Disposal - Subtitle C	CY	363,069	$ 244	$ 88,600,000
Transportation & Disposal - Barge Dewatering Effluent	CY	363,069	$ 88	$ 32,000,000
Disposal Testing	LS	1	$ 131,600	$ 100,000
Subtotal Transportation & Disposal				**$ 120,700,000**
SUBTOTAL DIRECT CAPITAL COSTS				**$ 268,200,000**
CONTINGENCY (25%)				**$ 67,100,000**
TOTAL DIRECT CAPITAL COSTS				**$ 335,300,000**

Table G-1a. Alternative 2 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
INDIRECT CAPITAL COSTS[d]				
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**
Coordination with Agencies/Stakeholders	%	0.5	TDCC	**$ 1,700,000**
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 23,500,000**
Project Management	%	5	TDCC	**$ 16,800,000**
TOTAL INDIRECT CAPITAL COSTS				**$ 113,000,000**
TOTAL CAPITAL COSTS				
TOTAL CAPITAL COSTS				**$ 448,300,000**
ANNUAL OMM COSTS[d]				
Reporting[h]	YR	1	$ 100,000	**$ 100,000**
Institutional Controls[h]	YR	1	$ 525,000	**$ 500,000**
Technical Support[h]	YR	1	$ 90,000	**$ 100,000**
SUBTOTAL ANNUAL OMM COSTS				**$ 700,000**
CONTINGENCY (25%)				**$ 200,000**
TOTAL ANNUAL OMM COSTS				**$ 900,000**
PERIODIC COSTS[d]				
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**
Cap Monitoring	EVENT	7	$ 54,000	**$ 400,000**
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**
Cap Maintenance (Year 0 through Year 15)	EVENT	3	$ 1,495,200	**$ 4,500,000**
Cap Maintenance (Year 16 through Year 35)	EVENT	4	$ 747,600	**$ 3,000,000**
SUBTOTAL PERIODIC COSTS				**$ 39,700,000**
CONTINGENCY (25%)				**$ 9,900,000**
TOTAL PERIODIC COSTS				**$ 49,600,000**

Table G-1a. Alternative 2 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
PRESENT WORTH COSTS (7% Discount; T=30 Years After Construction)				
Capital Costs				$ 392,200,000
Annual OMM				$ 8,300,000
Periodic Costs				$ 19,600,000
TOTAL PRESENT WORTH				**$ 420,100,000**

Notes:

AC = acre
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
LS = lump sum
OMM = operation, maintenance, and monitoring
ROD = Record of Decision
TDCC = total direct capital costs
TN = ton
YR = year

[a]Approximate totals are rounded to the nearest $100,000.

[b]15% scope contingency and 10% bid contingency. These contingencies are near baseline values specified in the EPA cost guidance document (USEPA 2000).

[c]Per EPA cost guidance (USEPA 2000), discount rate is 7%.

[d]This estimate represents costs with +50/-30% accuracy. All assumptions and costs are only for feasibility study purposes and are subject to refinement in the ROD and during remedial design.

[e]5% of material and installation costs; see Tables G-1c and G-1d sheet for details.

[f]Unit cost reflects weighted average of estimated unit costs for each bucket size/type (3 CY, 5 CY, and land-based) by their proportional use. See Table G-1c for details.

[g]Unit cost reflects weighted average of estimated unit costs for each material type (sand, armor/stone, and shoal habitat reconstruction material) by their estimated proportional use. See Table G-1d for details.

[h]Annual cost starts in Year 5 and continues until 30 years after construction.

Table G-1b. Alternative 2 DIRECT CAPITAL COSTS, Construction Staging Facility
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Staging Area Land Purchase/Lease	AC	5	$ 200,000	**$ 1,000,000**	Property used for contractor trailers, sample processing, equipment storage, and parking.	Based on average purchase price of selected potentially vacant sites from NY/NJ tax records. Properties were selected based on availability, proximity, size, accessibility, and upgrade requirements in the 2015 Draft Lower Passaic River Feasibility Study (Appendix C). Some properties were not included in the cost analysis because cost data was unavailable. A few properties were excluded because they had high, outlying unit costs. Costs are accurate to 2018. Selected locations were: Block 586, Lot 8, Linden NJ ($3.57/SF) Block 587, Lot 8, Linden NJ ($9.31/SF) Block 1, Lot 9, Kearny, NJ ($1.77/SF) Block 1, Lot 10, Kearny, NJ ($1.84/SF) Block 1, Lot 12, Kearny, NJ ($2.03/SF) Block 1, Lot 12.01, Kearny, NJ ($1.22/SF) Block 5014, Lot 1.01, Newark , NJ ($5.00/SF) Block 5070, Lot 3, Newark, NJ ($9.69/SF) Block 5070, Lot 5, Newark, NJ ($8.04/SF) Average unit cost is $4.72/SF or about $200,000/AC. Assumes the parcel will be in a condition that permits immediate installation of support facilities. Alternatively, this land could be leased.
Support Facilities	YR	4	$ 310,000	**$ 1,340,949**	See Design Criteria in Appendix A.	RS Means 2019; Reference numbers: 015213200550, Office trailer, furnished, rent per month, 50' x 12', excl. hookups. 015213400100, Field office expense, office equipment rental, average. 015213400120, Field office expense, office supplies, average. 015213201250, Storage boxes rent per month, 20' x 8'. 015113800700, Temporary utilities, temporary construction water bill per month, average. 015213400140, Field office expense, telephone bill; average bill/month, incl. long distance. 015113800600, Temporary utilities, power for job duration incl elevator etc., minimum. Per 100 square feet of floor. 015433403000, Rent space heaters oil or electric 100 MBH. 015213400160, Field office expense, field office lights and HVAC. 015433406410, Rent toilet, portable chemical. 323113200920, Fence, chain link industrial, galvanized steel, 6 ga. wire, 2-1/2" posts at 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire. 323113205090, Fence, chain link industrial, double swing gates, 8' high, 20' opening, includes excavation, posts, and hardware in concrete. 015632500100, Watchman, security service, uniformed person, monthly bases, max ($58.05/HR). Car rental unit cost from www.avis.com.
			Subtotal Construction Staging Facility	**$ 2,340,949**		

Notes:
AC = acre
YR = year

Table G-1c. Alternative 2 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	LS	1				
Dredging Equipment	%	5	$ 25,208,840	$ 1,260,442		Based on project experience. Percent of mechanical dredging costs including land-based dredging costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Critical Structure Protection Equipment	%	5	$ 1,200,000	$ 60,000		Based on project experience. Percent of critical structure protection costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
			Subtotal	**$ 1,320,442**		
Protections & Controls	LS	1				
Turbidity Control	LF	5,000	$ 44	$ 220,000	Each dredge system will utilize 1,000 LF of turbidity curtain. Assume that one spare set is always available and a set must be fully replaced each year.	Includes purchase, installation, and removal of silt curtain. Based on vendor communication with EnviroUSA (among other similar vendors): material is $25.95/LF, lump sum of $5774 for delivery of 1000 LF. Assume 16-hour installation x 2 installers (at $120/HR) on a boat ($2000 lump sum) to install 1000 LF. Assume the same for removal. Assume additional 10% of the material cost for maintenance during lifetime of one year. Unit cost of turbidity curtain per LF = $25.95/LF * 1.1 + $5.77/LF + (((2 installers * 16 hours * 2 events * $120) + $2,000) / 1,000 LF).
Critical Structure/Utility Protection	LS	1	$ 1,200,000	$ 1,200,000		This is a placeholder value, estimated based on project experience and the extent of potential critical structures and utilities in the upper 9-miles of the LPR. Design will seek to minimize reliance on protection.
			Subtotal	**$ 1,420,000**		
Mechanical Dredging	LS	1				
Small 3 CY Dredge	CY	179,588	$ 70	$ 12,571,137	See Design Criteria in Appendix A.	Multiple completed dredging projects were considered; three were selected as both being the most similar and having all the relevant information available. 1. LPR Phase I Removal Action Final Construction Report, (Main Text and Appendix C) (2013): Dredging unit cost was $58/CY (including mobilization/demobilization) for 41,434 CY for one 5-CY environmental bucket, with a dredge rate of 500 CY/DAY, working 12-hour days. 2. Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018): Dredging cost was $1,137,000 (including delivery) for 15,742 CY for one 2.6-CY environmental bucket, with a dredge rate of 394 CY/DAY. Estimated reduction to cost for delivery means unit cost is $65/CY. 3. Reynolds Metals Massena MCSS Database Release (2004): Dredging cost was $5,000,000 for 85,600 CY for two 5-1/2 and one 2-1/2 CY bucket environmental bucket, with a dredge rate of 873 CY/DAY working 20-hour days. Unit cost equals $58/CY. First, used the dredge rate and bucket size information from Phase 1 and RM 10.9 to perform a linear regression analysis to find the production rate in CY/HOUR for a 3- and 5-CY bucket (35 and 42 CY/HOUR, respectively). Assumed land-based removal has the same rate as the 3-CY dredge bucket. Then, used all three removals above to perform linear regression analysis of hourly dredge rate and cost per cubic yard. Cost ($/CY) = -0.6653 * (Rate [CY/HOUR]) + 86.675. Applied a nominal 8.45% escalation to represent inflation rate. Assumed a 30% escalation factor to land-based dredging, to account for added cost of construction haul roads and access issues.
Medium 5 CY Dredge	CY	155,023	$ 65	$ 10,076,525	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
Land-Based	CY	28,458	$ 90	$ 2,561,178	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
			Subtotal	**$ 25,208,840**	See Design Criteria in Appendix A.	
Debris Removal	DY	585	$ 3,880	**$ 2,269,512**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Actual cost of debris management and environmental protection was $144,500 and total number of dredging days was 40. Adjusted to 2019 dollars with inflation.
Bathymetric Verification Survey	DY	663	$ 5,600	**$ 3,715,184**	See Design Criteria in Appendix A.	Daily bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC). Consistent with the Lower 8.3-Mile ROD, which assumes the surveyors can complete 1 RM per day or 30 acres/day (8-hour day). Includes verification surveys performed before dredging, after dredging, and after each layer of cap material is placed. Includes labor and equipment.

Table G-1c. Alternative 2 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Water Quality Monitoring	DY	663	$ 11,000	**$ 7,297,684**	See Design Criteria in Appendix A.	Based on project experience, consistent with Lower 8.3-Mile ROD (USEPA 2016). Assumes intensive sampling to support completion certification.
Additional Construction Performance Monitoring	YR	5	$ 1,000,000	**$ 5,000,000**	See Design Criteria in Appendix A.	Based on project experience. May include air quality, sediment, and/or biological monitoring. Lab costs are included.
Monitoring Reporting	YR	5	$ 150,000	**$ 750,000**	See Design Criteria in Appendix A.	Based on project experience.
Barge Unloading/Material Handling	CY	363,069	$ 15	**$ 5,413,354**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Dredging and delivery cost is listed as $1,137,000 total. The total dredged CY for the RM 10.9 removal is 15,742 CY (Table 2-1). Assume 20% of dredging and delivery cost is barge unloading/material handling.
			Subtotal Dredging	**$ 52,395,015**		

Notes:
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LF = linear feet
LS = lump sum
ROD = Record of Decision
YR = year

Table G-1d. Alternative 2 DIRECT CAPITAL COSTS, Capping
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	%	5	$ 18,055,405	**$ 902,770**		Based on project experience. Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Material Purchase and Delivery	LS	1				
Sand	CY	218,425	$ 30	$ 6,585,520	Sand is 75% of cap material volume. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Armor/Stone	CY	72,808	$ 36	$ 2,640,761	Armor/stone is conservatively assumed to be 25% of cap material volume. See Design Criteria in Appendix A.	RS Means 2019 030513251050: Aggregate, stone, 3/4" to 1-1/2".
Shoal Habitat Reconstruction Material	CY	71,835	$ 71	$ 5,134,052	Material is 40% (one-foot-thick layer) of cap volume in of shoals. See Design Criteria in Appendix A.	Based on actual unit cost for habitat reconstruction material from the Thea Foss Waterway remediation, found in the Slip 4 Early Action Area 100% Design Submittal Design Analysis Report - Appendix G. Cost Estimate Back-up, Unit Costs (Actuals) Table. Of three reported actual unit costs, selected the most conservative (Thea Foss Waterway - Head) which is $38/TN. Assuming 1 CY habitat material = 1.5 TN, unit cost per cubic yard is $57/TN in 2006 dollars. Added escalation factor to convert to 2019 dollars.
			Subtotal	**$ 14,360,333**		
Onsite Material Handling & Placement	CY	363,069	$ 50	**$ 18,055,405**	See Design Criteria in Appendix A.	See backup for Sand.
Residual Management	LS	1				
Material Purchase and Delivery	CY	14,523	$ 30	$ 437,861	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
Material Placement	CY	14,523	$ 50	$ 722,216	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
			Subtotal	**$ 1,160,077**		
			Subtotal Capping	**$ 34,478,584**		

Notes:
CY = cubic yard
LS = lump sum

Table G-1e. Alternative 2 DIRECT CAPITAL COSTS, Dredged Material Processing
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Sediment Processing at Commercial Facility	CY	363,069	$ 160	**$ 58,090,986**	See Design Criteria in Appendix A.	Based on vendor communication with Clean Earth, and project experience assuming stabilization/solidification treatment similar to RM 10.9 removal action. Includes barge dewatering. Estimated sediment processing alone at $60 - $94/TON, converting to $76-$119/CY based on site characteristics (i.e. sediment density estimated at 1.27 TON/CY). Selected $100/CY as nominal mid-range value. Cost did not include barge dewatering. Barge dewatering assumed to be an additional 60% of sediment processing cost, based on engineering judgment. Considered Sediment Processing Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018) of $195/CY as an upper limit to sediment processing cost for a smaller project.
	Subtotal Dredged Material Processing			**$ 58,090,986**		

Notes:
CY = cubic yard
LS = lump sum
YR = year

Table G-1f. Alternative 2 DIRECT CAPITAL COSTS, Transportation & Disposal
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Transportation & Disposal - Subtitle C	CY	363,069	$ 244	**$ 88,588,754**	See Design Criteria in Appendix A.	Transportation and Disposal - Subtitle C includes transport of debris and sediment. Transportation & Disposal to Subtitle C and Barge dewatering Efflent combined unit costs are based on the Transportation & Disposal cost in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018), which was $5,230,000 for 15,742 CY of in-place sediment, or $332/CY sediment. This cost included dewatered sediment transportation and disposal at a Subtitle C landfill and transportation and disposal of the barge dewatering effluent to a water treatment plant in Baltimore. The same total was assumed, which considers both economies of scale and cost increases from 2013 to 2019. These costs have been distributed in alignment with the LPR Phase I Removal Action Final Construction report (text and Appendix C) (2013) - Transportation and Disposal cost of $10.12MM for 41,434 CY of in-place sediment (Table 3-1). As above, the same total was assumed, which considers both economies of scale and cost increases from 2012 to 2019. The unit cost is $244/CY for transportation and disposal of sediment at a subtitle C facility. The transportation & disposal of the barge dewatering effluent is estimated to be the difference between $332/CY and $244/CY at $88/CY, to retain the same overall cost.
Transportation & Disposal - Barge Dewatering Effluent	CY	363,069	$ 88	**$ 31,950,042**	See Design Criteria in Appendix A.	Includes barge effluent water transport and treatment. See backup for Transportation and Disposal - Subtitle C.
Disposal Testing	LS	1				
TCLP Waste Characterization	EA	128	$ 1,000	$ 128,422	One test for every 5,000 CY of dewatered material.	Includes analysis, shipping, and data validation costs, based on project experience. Based on vendor communication with ALS: TCLP analytical cost is $840/sample, shipping is $130/cooler, and data validation is about $134/sample, based on internal rates. Assume 4 samples per cooler.
Paint Filter Tests	EA	128	$ 25	$ 3,211	One test for every 5,000 CY of dewatered material.	Based on Lower 8.3-Mile ROD (USEPA 2016).
			Subtotal	**$ 131,632**		
			Subtotal Transportation & Disposal	**$ 120,670,428**		

Notes:
CY = cubic yard
LS = lump sum
TCLP = toxicity characteristic leaching procedure
TN = ton

Table G-1g. Alternative 2 INDIRECT CAPITAL COSTS
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**		Backup provided in Appendix G, Section 2: Basis of Estimates. Pre-design investigation (PDI) includes sediment sampling on 80-ft centers and estimated costs for supporting surveys (e.g., debris, habitat, and cultural surveys) and testing (e.g., sediment processing and water).
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**		Approximately 6% of TDCC, based on best professional judgement and project experience; not expected to vary with alternatives. Includes services to design the remedial action, design analysis, preliminary/intermediate/final design, plans & specifications, and cost estimate. This item does not include pre-design sampling or surveys.
Coordination with Agency/Stakeholders	%	0.5	TDCC	**$ 1,676,500**		Based on project experience.
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 23,471,000**		Based on project experience and EPA guidance (USEPA 2000). Includes agency oversight during construction, confirmation sampling, community air monitoring, services to manage construction or installation of remedial action, excluding any similar services provided as part of construction activities; includes submittal review, change order review, design modifications, construction observation, construction survey, construction schedule tracking, QA/QC documentation, OMM manual, and record drawings.
Project Management	%	5	TDCC	**$ 16,765,000**		Based on project experience and EPA guidance (USEPA 2000). Includes services to support construction or installation of remedial action, not specific to remedial design or construction management; includes planning, community relations, bid/contract administration, cost and performance reporting, permitting, legal, and construction completion report.
			Subtotal Indirect Capital Costs	**$ 112,912,500**		

Notes:
LS = lump sum
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
OMM = operation, maintenance, and monitoring
PDI = Pre-design Investigation
QA/QC = quality assurance and quality control
TDCC = total direct capital costs

Table G-1h. Alternative 2 ANNUAL OPERATION, MAINTENANCE, AND MONITORING COSTS
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Reporting	YR	1	$ 100,000	**$ 100,000**	Includes annual tissue and water quality monitoring reports.	Estimated based on project experience
Institutional Controls	YR	1	$ 525,000	**$ 525,000**	Includes informational devices, propriety controls, and enforcement tools.	Estimated based on project experience
Technical Support	YR	1	$ 90,000	**$ 90,000**	Represents OMM portion of agency oversight, project coordination.	Calculated based on approximately 15% of OMM costs before contingency, based on EPA guidance (USEPA 2000).
		Subtotal Annual OMM		**$ 715,000**		

Notes:

OMM = operation, maintenance, and monitoring

RD/RA = remedial design/remedial action

YR = year

Table G-1i. Alternative 2 PERIODIC COSTS
2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**	14 events occur, annually for the first 10 years after the end of construction, and then in years 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates. Includes biota sampling, sediment profile imaging survey, and water quality monitoring.
Cap Monitoring	EVENT	7	$ 54,000	**$ 378,000**	7 events occur, in years 5, 10, 15, 20, 25, 30, and 35 after the start of construction.	Estimated based on project experience; cap monitoring will include bathymetric surveys and chemical monitoring. Based on footprint area of alternative monitored; assumes $600/acre for monitoring work.
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Estimated based on project experience. Surveys performed opportunistically (e.g., after high flow event) over entire reach. Bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC).
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**	1 event occurs, in year 5 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Cap Maintenance (Year 0 through Year 15)	EVENT	3			3 events occur, in years 5, 10, and 15 after the start of construction.	
Mobilization/Demobilization	%	5	$ 902,770	$ 45,139		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	18,153	$ 30	$ 547,326	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Onsite Material Handling & Placement	CY	18,153	$ 50	$ 902,770	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See backup for Material Purchase and Delivery.
			Subtotal	**$ 1,495,235**		
Cap Maintenance (Year 16 through Year 35)	EVENT	4			4 events occur, in years 20, 25, 30, and 35 after the start of construction.	
Mobilization/Demobilization	%	5	$ 451,385	$ 22,569		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	9,077	$ 30	$ 273,663	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
Onsite Material Handling & Placement	CY	9,077	$ 50	$ 451,385	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
			Subtotal	**$ 747,617**		
			Subtotal Periodic Costs	**$ 24,254,174**		

Notes:
CY = cubic yard
LPR = Lower Passaic River

Table G-2a. Alternative 3 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
KEY ASSUMPTIONS				
Contingency[b]	%	25		
Discount rate, i[c]	%	7.0		
DIRECT CAPITAL COSTS[d]				
Construction Staging Facility				
Staging Area Land Purchase/Lease	AC	5	$ 200,000	$ 1,000,000
Support Facilities	YR	5	$ 310,000	$ 1,400,000
Subtotal Construction Staging Facility				**$ 2,400,000**
Dredging				
Mobilization/Demobilization[e]	LS	1	$ 1,403,300	$ 1,400,000
Protections & Controls	LS	1	$ 1,420,000	$ 1,400,000
Mechanical Dredging[f]	CY	387,391	$ 69	$ 26,900,000
Debris Removal	DY	625	$ 3,880	$ 2,400,000
Bathymetric Verification Survey	DY	703	$ 5,600	$ 3,900,000
Water Quality Monitoring	DY	703	$ 11,000	$ 7,700,000
Additional Construction Performance Monitoring	YR	5	$ 1,000,000	$ 5,000,000
Monitoring Reporting	YR	5	$ 150,000	$ 800,000
Barge Unloading/Material Handling	CY	387,391	$ 15	$ 5,800,000
Subtotal Dredging				**$ 55,300,000**
Capping				
Mobilization/Demobilization[e]	LS	1	$ 963,200	$ 1,000,000
Material Purchase & Delivery[g]	CY	387,391	$ 40	$ 15,300,000
On-Site Material Handling & Placement	CY	387,391	$ 50	$ 19,400,000
Residual Management	LS	1	$ 1,237,800	$ 1,200,000
Subtotal Capping				**$ 36,900,000**
Dredged Material Processing				
Sediment Processing at Commercial Facility	CY	387,391	$ 160	$ 62,000,000
Subtotal Dredged Material Processing				**$ 62,000,000**
Transportation & Disposal				
Transportation & Disposal - Subtitle C	CY	387,391	$ 244	$ 94,500,000
Transportation & Disposal - Barge Dewatering Effluent	CY	387,391	$ 88	$ 34,100,000
Disposal Testing	LS	1	$ 140,400	$ 100,000
Subtotal Transportation & Disposal				**$ 128,700,000**
SUBTOTAL DIRECT CAPITAL COSTS				**$ 285,300,000**
CONTINGENCY (25%)				**$ 71,300,000**
TOTAL DIRECT CAPITAL COSTS				**$ 356,600,000**

Table G-2a. Alternative 3 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
INDIRECT CAPITAL COSTS[d]				
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**
Coordination with Agencies/Stakeholders	%	0.5	TDCC	**$ 1,800,000**
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 25,000,000**
Project Management	%	5	TDCC	**$ 17,800,000**
TOTAL INDIRECT CAPITAL COSTS				**$ 115,600,000**
TOTAL CAPITAL COSTS				
TOTAL CAPITAL COSTS				**$ 472,200,000**
ANNUAL OMM COSTS[d]				
Reporting[h]	YR	1	$ 100,000	**$ 100,000**
Institutional Controls[h]	YR	1	$ 525,000	**$ 500,000**
Technical Support[h]	YR	1	$ 90,000	**$ 100,000**
SUBTOTAL ANNUAL OMM COSTS				**$ 700,000**
CONTINGENCY (25%)				**$ 200,000**
TOTAL ANNUAL OMM COSTS				**$ 900,000**
PERIODIC COSTS[d]				
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**
Cap Monitoring	EVENT	7	$ 57,600	**$ 400,000**
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**
Cap Maintenance (Year 0 through Year 15)	EVENT	3	$ 1,595,400	**$ 4,800,000**
Cap Maintenance (Year 16 through Year 35)	EVENT	4	$ 797,700	**$ 3,200,000**
SUBTOTAL PERIODIC COSTS				**$ 40,200,000**
CONTINGENCY (25%)				**$ 10,100,000**
TOTAL PERIODIC COSTS				**$ 50,300,000**

Table G-2a. Alternative 3 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
PRESENT WORTH COSTS (7% Discount; T=30 Years After Construction)				
Capital Costs				$ 412,600,000
Annual OMM				$ 8,300,000
Periodic Costs				$ 19,900,000
TOTAL PRESENT WORTH				**$ 440,800,000**

Notes:

AC = acre
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
LS = lump sum
OMM = operation, maintenance, and monitoring
ROD = Record of Decision
TDCC = total direct capital costs
TN = ton
YR = year

[a]Approximate totals are rounded to the nearest $100,000.

[b]15% scope contingency and 10% bid contingency. These contingencies are near baseline values specified in the EPA cost guidance document (USEPA 2000).

[c]Per EPA cost guidance (USEPA 2000), discount rate is 7%.

[d]This estimate represents costs with +50/-30% accuracy. All assumptions and costs are only for feasibility study purposes and are subject to refinement in the ROD and during remedial design.

[e]5% of material and installation costs; see Tables G-2c and G-2d sheet for details.

[f]Unit cost reflects weighted average of estimated unit costs for each bucket size/type (3 CY, 5 CY, and land-based) by their proportional use. See Table G-2c for details.

[g]Unit cost reflects weighted average of estimated unit costs for each material type (sand, armor/stone, and shoal habitat reconstruction material) by their estimated proportional use. See Table G-2d for details.

[h]Annual cost starts in Year 5 and continues until 30 years after construction.

Table G-2b. Alternative 3 DIRECT CAPITAL COSTS, Construction Staging Facility
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Staging Area Land Purchase/Lease	AC	5	$ 200,000	**$ 1,000,000**	Property used for contractor trailers, sample processing, equipment storage, and parking.	Based on average purchase price of selected potentially vacant sites from NY/NJ tax records. Properties were selected based on availability, proximity, size, accessibility, and upgrade requirements in the 2015 Draft Lower Passaic River Feasibility Study (Appendix C). Some properties were not included in the cost analysis because cost data was unavailable. A few properties were excluded because they had high, outlying unit costs. Costs are accurate to 2018. Selected locations were: Block 586, Lot 8, Linden NJ ($3.57/SF) Block 587, Lot 8, Linden NJ ($9.31/SF) Block 1, Lot 9, Kearny, NJ ($1.77/SF) Block 1, Lot 10, Kearny, NJ ($1.84/SF) Block 1, Lot 12, Kearny, NJ ($2.03/SF) Block 1, Lot 12.01, Kearny, NJ ($1.22/SF) Block 5014, Lot 1.01, Newark , NJ ($5.00/SF) Block 5070, Lot 3, Newark, NJ ($9.69/SF) Block 5070, Lot 5, Newark, NJ ($8.04/SF) Average unit cost is $4.72/SF or about $200,000/AC. Assumes the parcel will be in a condition that permits immediate installation of support facilities. Alternatively, this land could be leased.
Support Facilities	YR	5	$ 310,000	**$ 1,419,316**	See Design Criteria in Appendix A.	RS Means 2019; Reference numbers: 015213200550, Office trailer, furnished, rent per month, 50' x 12', excl. hookups. 015213400100, Field office expense, office equipment rental, average. 015213400120, Field office expense, office supplies, average. 015213201250, Storage boxes rent per month, 20' x 8'. 015113800700, Temporary utilities, temporary construction water bill per month, average. 015213400140, Field office expense, telephone bill; average bill/month, incl. long distance. 015113800600, Temporary utilities, power for job duration incl elevator etc., minimum. Per 100 square feet of floor. 015433403000, Rent space heaters oil or electric 100 MBH. 015213400160, Field office expense, field office lights and HVAC. 015433406410, Rent toilet, portable chemical. 323113200920, Fence, chain link industrial, galvanized steel, 6 ga. wire, 2-1/2" posts at 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire. 323113205090, Fence, chain link industrial, double swing gates, 8' high, 20' opening, includes excavation, posts, and hardware in concrete. 015632500100, Watchman, security service, uniformed person, monthly bases, max ($58.05/HR). Car rental unit cost from www.avis.com.
			Subtotal Construction Staging Facility	**$ 2,419,316**		

Notes:
AC = acre
YR = year

Table G-2c. Alternative 3 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	LS	1				
Dredging Equipment	%	5	$ 26,865,072	$ 1,343,254		Based on project experience. Percent of mechanical dredging costs including land-based dredging costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Critical Structure Protection Equipment	%	5	$ 1,200,000	$ 60,000		Based on project experience. Percent of critical structure protection costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
			Subtotal	**$ 1,403,254**		
Protections & Controls	LS	1				
Turbidity Control	LF	5,000	$ 44	$ 220,000	Each dredge system will utilize 1,000 LF of turbidity curtain. Assume that one spare set is always available and a set must be fully replaced each year.	Includes purchase, installation, and removal of silt curtain. Based on vendor communication with EnviroUSA (among other similar vendors): material is $25.95/LF, lump sum of $5774 for delivery of 1000 LF. Assume 16-hour installation x 2 installers (at $120/HR) on a boat ($2000 lump sum) to install 1000 LF. Assume the same for removal. Assume additional 10% of the material cost for maintenance during lifetime of one year. Unit cost of turbidity curtain per LF = $25.95/LF * 1.1 + $5.77/LF + (((2 installers * 16 hours * 2 events * $120) + $2,000) / 1,000 LF).
Critical Structure/Utility Protection	LS	1	$ 1,200,000	$ 1,200,000		This is a placeholder value, estimated based on project experience and the extent of potential critical structures and utilities in the upper 9-miles of the LPR. Design will seek to minimize reliance on protection.
			Subtotal	**$ 1,420,000**		
Mechanical Dredging	LS	1				
Small 3 CY Dredge	CY	191,085	$ 70	$ 13,375,945	See Design Criteria in Appendix A.	Multiple completed dredging projects were considered; three were selected as both being the most similar and having all the relevant information available. 1. LPR Phase I Removal Action Final Construction Report, (Main Text and Appendix C) (2013): Dredging unit cost was $58/CY (including mobilization/demobilization) for 41,434 CY for one 5-CY environmental bucket, with a dredge rate of 500 CY/DAY, working 12-hour days. 2. Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018): Dredging cost was $1,137,000 (including delivery) for 15,742 CY for one 2.6-CY environmental bucket, with a dredge rate of 394 CY/DAY. Estimated reduction to cost for delivery means unit cost is $65/CY. 3. Reynolds Metals Massena MCSS Database Release (2004): Dredging cost was $5,000,000 for 85,600 CY for two 5-1/2 and one 2-1/2 CY bucket environmental bucket, with a dredge rate of 873 CY/DAY working 20-hour days. Unit cost equals $58/CY. First, used the dredge rate and bucket size information from Phase 1 and RM 10.9 to perform a linear regression analysis to find the production rate in CY/HOUR for a 3- and 5-CY bucket (35 and 42 CY/HOUR, respectively). Assumed land-based removal has the same rate as the 3-CY dredge bucket. Then, used all three removals above to perform linear regression analysis of hourly dredge rate and cost per cubic yard. Cost ($/CY) = -0.6653 * (Rate [CY/HOUR]) + 86.675. Applied a nominal 8.45% escalation to represent inflation rate. Assumed a 30% escalation factor to land-based dredging, to account for added cost of construction haul roads and access issues.
Medium 5 CY Dredge	CY	167,138	$ 65	$ 10,863,984	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
Land-Based	CY	29,168	$ 90	$ 2,625,143	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
			Subtotal	**$ 26,865,072**	See Design Criteria in Appendix A.	
Debris Removal	DY	625	$ 3,880	**$ 2,423,506**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Actual cost of debris management and environmental protection was $144,500 and total number of dredging days was 40. Adjusted to 2019 dollars with inflation.
Bathymetric Verification Survey	DY	703	$ 5,600	**$ 3,937,443**	See Design Criteria in Appendix A.	Daily bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC). Consistent with the Lower 8.3-Mile ROD, which assumes the surveyors can complete 1 RM per day or 30 acres/day (8-hour day). Includes verification surveys performed before dredging, after dredging, and after each layer of cap material is placed. Includes labor and equipment.

Table G-2c. Alternative 3 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Water Quality Monitoring	DY	703	$ 11,000	**$ 7,734,263**	See Design Criteria in Appendix A.	Based on project experience, consistent with Lower 8.3-Mile ROD (USEPA 2016). Assumes intensive sampling to support completion certification.
Additional Construction Performance Monitoring	YR	5	$ 1,000,000	**$ 5,000,000**	See Design Criteria in Appendix A.	Based on project experience. May include air quality, sediment, and/or biological monitoring. Lab costs are included.
Monitoring Reporting	YR	5	$ 150,000	**$ 750,000**	See Design Criteria in Appendix A.	Based on project experience.
Barge Unloading/Material Handling	CY	387,391	$ 15	**$ 5,776,006**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Dredging and delivery cost is listed as $1,137,000 total. The total dredged CY for the RM 10.9 removal is 15,742 CY (Table 2-1). Assume 20% of dredging and delivery cost is barge unloading/material handling.
			Subtotal Dredging	**$ 55,309,543**		

Notes:
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LF = linear feet
LS = lump sum
ROD = Record of Decision
YR = year

Table G-2d. Alternative 3 DIRECT CAPITAL COSTS, Capping
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	%	5	$ 19,264,974	**$ 963,249**		Based on project experience. Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Material Purchase and Delivery	LS	1				
Sand	CY	233,218	$ 30	$ 7,031,525	Sand is 75% of cap material volume. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Armor/Stone	CY	77,739	$ 36	$ 2,819,606	Armor/stone is conservatively assumed to be 25% of cap material volume. See Design Criteria in Appendix A.	RS Means 2019 030513251050: Aggregate, stone, 3/4" to 1-1/2".
Shoal Habitat Reconstruction Material	CY	76,434	$ 71	$ 5,462,736	Material is 40% (one-foot-thick layer) of cap volume in of shoals. See Design Criteria in Appendix A.	Based on actual unit cost for habitat reconstruction material from the Thea Foss Waterway remediation, found in the Slip 4 Early Action Area 100% Design Submittal Design Analysis Report - Appendix G. Cost Estimate Back-up, Unit Costs (Actuals) Table. Of three reported actual unit costs, selected the most conservative (Thea Foss Waterway - Head) which is $38/TN. Assuming 1 CY habitat material = 1.5 TN, unit cost per cubic yard is $57/TN in 2006 dollars. Added escalation factor to convert to 2019 dollars.
			Subtotal	**$ 15,313,867**		
Onsite Material Handling & Placement	CY	387,391	$ 50	**$ 19,264,974**	See Design Criteria in Appendix A.	See backup for Sand.
Residual Management	LS	1				
Material Purchase and Delivery	CY	15,496	$ 30	$ 467,194	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
Material Placement	CY	15,496	$ 50	$ 770,599	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
			Subtotal	**$ 1,237,793**		
			Subtotal Capping	**$ 36,779,883**		

Notes:
CY = cubic yard
LS = lump sum

Table G-2e. Alternative 3 DIRECT CAPITAL COSTS, Dredged Material Processing
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Sediment Processing at Commercial Facility	CY	387,391	$ 160	**$ 61,982,624**	See Design Criteria in Appendix A.	Based on vendor communication with Clean Earth, and project experience assuming stabilization/solidification treatment similar to RM 10.9 removal action. Includes barge dewatering. Estimated sediment processing alone at $60 - $94/TON, converting to $76-$119/CY based on site characteristics (i.e. sediment density estimated at 1.27 TON/CY). Selected $100/CY as nominal mid-range value. Cost did not include barge dewatering. Barge dewatering assumed to be an additional 60% of sediment processing cost, based on engineering judgment. Considered Sediment Processing Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018) of $195/CY as an upper limit to sediment processing cost for a smaller project.
	Subtotal Dredged Material Processing			**$ 61,982,624**		

Notes:
CY = cubic yard
LS = lump sum
YR = year

Table G-2f. Alternative 3 DIRECT CAPITAL COSTS, Transportation & Disposal
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Transportation & Disposal - Subtitle C	CY	387,391	$ 244	**$ 94,523,501**	See Design Criteria in Appendix A.	Transportation and Disposal - Subtitle C includes transport of debris and sediment. Transportation & Disposal to Subtitle C and Barge dewatering Efflent combined unit costs are based on the Transportation & Disposal cost in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018), which was $5,230,000 for 15,742 CY of in-place sediment, or $332/CY sediment. This cost included dewatered sediment transportation and disposal at a Subtitle C landfill and transportation and disposal of the barge dewatering effluent to a water treatment plant in Baltimore. The same total was assumed, which considers both economies of scale and cost increases from 2013 to 2019. These costs have been distributed in alignment with the LPR Phase I Removal Action Final Construction report (text and Appendix C) (2013) - Transportation and Disposal cost of $10.12MM for 41,434 CY of in-place sediment (Table 3-1). As above, the same total was assumed, which considers both economies of scale and cost increases from 2012 to 2019. The unit cost is $244/CY for transportation and disposal of sediment at a subtitle C facility. The transportation & disposal of the barge dewatering effluent is estimated to be the difference between $332/CY and $244/CY at $88/CY, to retain the same overall cost.
Transportation & Disposal - Barge Dewatering Effluent	CY	387,391	$ 88	**$ 34,090,443**	See Design Criteria in Appendix A.	Includes barge effluent water transport and treatment. See backup for Transportation and Disposal - Subtitle C.
Disposal Testing	LS	1				
TCLP Waste Characterization	EA	137	$ 1,000	$ 136,983	One test for every 5,000 CY of dewatered material.	Includes analysis, shipping, and data validation costs, based on project experience. Based on vendor communication with ALS: TCLP analytical cost is $840/sample, shipping is $130/cooler, and data validation is about $134/sample, based on internal rates. Assume 4 samples per cooler.
Paint Filter Tests	EA	137	$ 25	$ 3,425	One test for every 5,000 CY of dewatered material.	Based on Lower 8.3-Mile ROD (USEPA 2016).
			Subtotal	**$ 140,408**		
			Subtotal Transportation & Disposal	**$ 128,754,352**		

Notes:
CY = cubic yard
LS = lump sum
TCLP = toxicity characteristic leaching procedure
TN = ton

Table G-2g. Alternative 3 INDIRECT CAPITAL COSTS
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**		Backup provided in Appendix G, Section 2: Basis of Estimates. Pre-design investigation (PDI) includes sediment sampling on 80-ft centers and estimated costs for supporting surveys (e.g., debris, habitat, and cultural surveys) and testing (e.g., sediment processing and water).
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**		Approximately 6% of TDCC, based on best professional judgement and project experience; not expected to vary with alternatives. Includes services to design the remedial action, design analysis, preliminary/intermediate/final design, plans & specifications, and cost estimate. This item does not include pre-design sampling or surveys.
Coordination with Agency/Stakeholders	%	0.5	TDCC	**$ 1,783,000**		Based on project experience.
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 24,962,000**		Based on project experience and EPA guidance (USEPA 2000). Includes agency oversight during construction, confirmation sampling, community air monitoring, services to manage construction or installation of remedial action, excluding any similar services provided as part of construction activities; includes submittal review, change order review, design modifications, construction observation, construction survey, construction schedule tracking, QA/QC documentation, OMM manual, and record drawings.
Project Management	%	5	TDCC	**$ 17,830,000**		Based on project experience and EPA guidance (USEPA 2000). Includes services to support construction or installation of remedial action, not specific to remedial design or construction management; includes planning, community relations, bid/contract administration, cost and performance reporting, permitting, legal, and construction completion report.
			Subtotal Indirect Capital Costs	**$ 115,575,000**		

Notes:
LS = lump sum
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
OMM = operation, maintenance, and monitoring
PDI = Pre-design Investigation
QA/QC = quality assurance and quality control
TDCC = total direct capital costs

Table G-2h. Alternative 3 ANNUAL OPERATION, MAINTENANCE, AND MONITORING COSTS
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Reporting	YR	1	$ 100,000	**$ 100,000**	Includes annual tissue and water quality monitoring reports.	Estimated based on project experience
Institutional Controls	YR	1	$ 525,000	**$ 525,000**	Includes informational devices, propriety controls, and enforcement tools.	Estimated based on project experience
Technical Support	YR	1	$ 90,000	**$ 90,000**	Represents OMM portion of agency oversight, project coordination.	Calculated based on approximately 15% of OMM costs before contingency, based on EPA guidance (USEPA 2000).
		Subtotal Annual OMM		**$ 715,000**		

Notes:

OMM = operation, maintenance, and monitoring

RD/RA = remedial design/remedial action

YR = year

Table G-2i. Alternative 3 PERIODIC COSTS
2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**	14 events occur, annually for the first 10 years after the end of construction, and then in years 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates. Includes biota sampling, sediment profile imaging survey, and water quality monitoring.
Cap Monitoring	EVENT	7	$ 57,600	**$ 403,200**	7 events occur, in years 5, 10, 15, 20, 25, 30, and 35 after the start of construction.	Estimated based on project experience; cap monitoring will include bathymetric surveys and chemical monitoring. Based on footprint area of alternative monitored; assumes $600/acre for monitoring work.
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Estimated based on project experience. Surveys performed opportunistically (e.g., after high flow event) over entire reach. Bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC).
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**	1 event occurs, in year 5 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Cap Maintenance (Year 0 through Year 15)	EVENT	3			3 events occur, in years 5, 10, and 15 after the start of construction.	
Mobilization/Demobilization	%	5	$ 963,249	$ 48,162		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	19,370	$ 30	$ 583,993	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Onsite Material Handling & Placement	CY	19,370	$ 50	$ 963,249	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See backup for Material Purchase and Delivery.
			Subtotal	**$ 1,595,404**		
Cap Maintenance (Year 16 through Year 35)	EVENT	4			4 events occur, in years 20, 25, 30, and 35 after the start of construction.	
Mobilization/Demobilization	%	5	$ 481,624	$ 24,081		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	9,685	$ 30	$ 291,996	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
Onsite Material Handling & Placement	CY	9,685	$ 50	$ 481,624	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
			Subtotal	**$ 797,702**		
			Subtotal Periodic Costs	**$ 24,780,218**		

Notes:
CY = cubic yard
LPR = Lower Passaic River

Table G-3a. Alternative 4 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
KEY ASSUMPTIONS				
Contingency[b]	%	25		
Discount rate, i[c]	%	7.0		
DIRECT CAPITAL COSTS[d]				
Construction Staging Facility				
Staging Area Land Purchase/Lease	AC	5	$ 200,000	$ 1,000,000
Support Facilities	YR	5	$ 310,000	$ 1,500,000
Subtotal Construction Staging Facility				**$ 2,500,000**
Dredging				
Mobilization/Demobilization[e]	LS	1	$ 1,512,000	$ 1,500,000
Protections & Controls	LS	1	$ 1,420,000	$ 1,400,000
Mechanical Dredging[f]	CY	419,405	$ 69	$ 29,000,000
Debris Removal	DY	671	$ 3,880	$ 2,600,000
Bathymetric Verification Survey	DY	750	$ 5,600	$ 4,200,000
Water Quality Monitoring	DY	750	$ 11,000	$ 8,200,000
Additional Construction Performance Monitoring	YR	5	$ 1,000,000	$ 5,000,000
Monitoring Reporting	YR	5	$ 150,000	$ 800,000
Barge Unloading/Material Handling	CY	419,405	$ 15	$ 6,300,000
Subtotal Dredging				**$ 59,000,000**
Capping				
Mobilization/Demobilization[e]	LS	1	$ 1,042,800	$ 1,000,000
Material Purchase & Delivery[g]	CY	419,405	$ 39	$ 16,600,000
On-Site Material Handling & Placement	CY	419,405	$ 50	$ 21,000,000
Residual Management	LS	1	$ 1,340,100	$ 1,300,000
Subtotal Capping				**$ 39,900,000**
Dredged Material Processing				
Sediment Processing at Commercial Facility	CY	419,405	$ 160	$ 67,100,000
Subtotal Dredged Material Processing				**$ 67,100,000**
Transportation & Disposal				
Transportation & Disposal - Subtitle C	CY	419,405	$ 244	$ 102,300,000
Transportation & Disposal - Barge Dewatering Effluent	CY	419,405	$ 88	$ 36,900,000
Disposal Testing	LS	1	$ 152,100	$ 200,000
Subtotal Transportation & Disposal				**$ 139,400,000**
SUBTOTAL DIRECT CAPITAL COSTS				**$ 307,900,000**
CONTINGENCY (25%)				**$ 77,000,000**
TOTAL DIRECT CAPITAL COSTS				**$ 384,900,000**

Table G-3a. Alternative 4 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
INDIRECT CAPITAL COSTS[d]				
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**
Coordination with Agencies/Stakeholders	%	0.5	TDCC	**$ 1,900,000**
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 26,900,000**
Project Management	%	5	TDCC	**$ 19,200,000**
TOTAL INDIRECT CAPITAL COSTS				**$ 119,000,000**
TOTAL CAPITAL COSTS				
TOTAL CAPITAL COSTS				**$ 503,900,000**
ANNUAL OMM COSTS[d]				
Reporting[h]	YR	1	$ 100,000	**$ 100,000**
Institutional Controls[h]	YR	1	$ 525,000	**$ 500,000**
Technical Support[h]	YR	1	$ 90,000	**$ 100,000**
SUBTOTAL ANNUAL OMM COSTS				**$ 700,000**
CONTINGENCY (25%)				**$ 200,000**
TOTAL ANNUAL OMM COSTS				**$ 900,000**
PERIODIC COSTS[d]				
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**
Cap Monitoring	EVENT	7	$ 62,400	**$ 400,000**
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**
Cap Maintenance (Year 0 through Year 15)	EVENT	3	$ 1,727,200	**$ 5,200,000**
Cap Maintenance (Year 16 through Year 35)	EVENT	4	$ 863,600	**$ 3,500,000**
SUBTOTAL PERIODIC COSTS				**$ 40,900,000**
CONTINGENCY (25%)				**$ 10,200,000**
TOTAL PERIODIC COSTS				**$ 51,100,000**

Table G-3a. Alternative 4 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost[a]
PRESENT WORTH COSTS (7% Discount; T=30 Years After Construction)				
Capital Costs				$ 439,500,000
Annual OMM				$ 8,300,000
Periodic Costs				$ 20,200,000
TOTAL PRESENT WORTH				**$ 468,000,000**

Notes:

AC = acre
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
LS = lump sum
OMM = operation, maintenance, and monitoring
ROD = Record of Decision
TDCC = total direct capital costs
TN = ton
YR = year

[a]Approximate totals are rounded to the nearest $100,000.

[b]15% scope contingency and 10% bid contingency. These contingencies are near baseline values specified in the EPA cost guidance document (USEPA 2000).

[c]Per EPA cost guidance (USEPA 2000), discount rate is 7%.

[d]This estimate represents costs with +50/-30% accuracy. All assumptions and costs are only for feasibility study purposes and are subject to refinement in the ROD and during remedial design.

[e]5% of material and installation costs; see Tables G-3c and G-3d sheet for details.

[f]Unit cost reflects weighted average of estimated unit costs for each bucket size/type (3 CY, 5 CY, and land-based) by their proportional use. See Table G-3c for details.

[g]Unit cost reflects weighted average of estimated unit costs for each material type (sand, armor/stone, and shoal habitat reconstruction material) by their estimated proportional use. See Table G-3d for details.

[h]Annual cost starts in Year 5 and continues until 30 years after construction.

Table G-3b. Alternative 4 DIRECT CAPITAL COSTS, Construction Staging Facility
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Staging Area Land Purchase/Lease	AC	5	$ 200,000	**$ 1,000,000**	Property used for contractor trailers, sample processing, equipment storage, and parking.	Based on average purchase price of selected potentially vacant sites from NY/NJ tax records. Properties were selected based on availability, proximity, size, accessibility, and upgrade requirements in the 2015 Draft Lower Passaic River Feasibility Study (Appendix C). Some properties were not included in the cost analysis because cost data was unavailable. A few properties were excluded because they had high, outlying unit costs. Costs are accurate to 2018. Selected locations were: Block 586, Lot 8, Linden NJ ($3.57/SF) Block 587, Lot 8, Linden NJ ($9.31/SF) Block 1, Lot 9, Kearny, NJ ($1.77/SF) Block 1, Lot 10, Kearny, NJ ($1.84/SF) Block 1, Lot 12, Kearny, NJ ($2.03/SF) Block 1, Lot 12.01, Kearny, NJ ($1.22/SF) Block 5014, Lot 1.01, Newark , NJ ($5.00/SF) Block 5070, Lot 3, Newark, NJ ($9.69/SF) Block 5070, Lot 5, Newark, NJ ($8.04/SF) Average unit cost is $4.72/SF or about $200,000/AC. Assumes the parcel will be in a condition that permits immediate installation of support facilities. Alternatively, this land could be leased.
Support Facilities	YR	5	$ 310,000	**$ 1,511,380**	See Design Criteria in Appendix A.	RS Means 2019; Reference numbers: 015213200550, Office trailer, furnished, rent per month, 50' x 12', excl. hookups. 015213400100, Field office expense, office equipment rental, average. 015213400120, Field office expense, office supplies, average. 015213201250, Storage boxes rent per month, 20' x 8'. 015113800700, Temporary utilities, temporary construction water bill per month, average. 015213400140, Field office expense, telephone bill; average bill/month, incl. long distance. 015113800600, Temporary utilities, power for job duration incl elevator etc., minimum. Per 100 square feet of floor. 015433403000, Rent space heaters oil or electric 100 MBH. 015213400160, Field office expense, field office lights and HVAC. 015433406410, Rent toilet, portable chemical. 323113200920, Fence, chain link industrial, galvanized steel, 6 ga. wire, 2-1/2" posts at 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire. 323113205090, Fence, chain link industrial, double swing gates, 8' high, 20' opening, includes excavation, posts, and hardware in concrete. 015632500100, Watchman, security service, uniformed person, monthly bases, max ($58.05/HR). Car rental unit cost from www.avis.com.
			Subtotal Construction Staging Facility	**$ 2,511,380**		

Notes:
AC = acre
YR = year

Table G-3c. Alternative 4 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	LS	1				
Dredging Equipment	%	5	$ 29,039,484	$ 1,451,974		Based on project experience. Percent of mechanical dredging costs including land-based dredging costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Critical Structure Protection Equipment	%	5	$ 1,200,000	$ 60,000		Based on project experience. Percent of critical structure protection costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
			Subtotal	**$ 1,511,974**		
Protections & Controls	LS	1				
Turbidity Control	LF	5,000	$ 44	$ 220,000	Each dredge system will utilize 1,000 LF of turbidity curtain. Assume that one spare set is always available and a set must be fully replaced each year.	Includes purchase, installation, and removal of silt curtain. Based on vendor communication with EnviroUSA (among other similar vendors): material is $25.95/LF, lump sum of $5774 for delivery of 1000 LF. Assume 16-hour installation x 2 installers (at $120/HR) on a boat ($2000 lump sum) to install 1000 LF. Assume the same for removal. Assume additional 10% of the material cost for maintenance during lifetime of one year. Unit cost of turbidity curtain per LF = $25.95/LF * 1.1 + $5.77/LF + (((2 installers * 16 hours * 2 events * $120) + $2,000) / 1,000 LF).
Critical Structure/Utility Protection	LS	1	$ 1,200,000	$ 1,200,000		This is a placeholder value, estimated based on project experience and the extent of potential critical structures and utilities in the upper 9-miles of the LPR. Design will seek to minimize reliance on protection.
			Subtotal	**$ 1,420,000**		
Mechanical Dredging	LS	1				
Small 3 CY Dredge	CY	205,261	$ 70	$ 14,368,274	See Design Criteria in Appendix A.	Multiple completed dredging projects were considered; three were selected as both being the most similar and having all the relevant information available. 1. LPR Phase I Removal Action Final Construction Report, (Main Text and Appendix C) (2013): Dredging unit cost was $58/CY (including mobilization/demobilization) for 41,434 CY for one 5-CY environmental bucket, with a dredge rate of 500 CY/DAY, working 12-hour days. 2. Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018): Dredging cost was $1,137,000 (including delivery) for 15,742 CY for one 2.6-CY environmental bucket, with a dredge rate of 394 CY/DAY. Estimated reduction to cost for delivery means unit cost is $65/CY. 3. Reynolds Metals Massena MCSS Database Release (2004): Dredging cost was $5,000,000 for 85,600 CY for two 5-1/2 and one 2-1/2 CY bucket environmental bucket, with a dredge rate of 873 CY/DAY working 20-hour days. Unit cost equals $58/CY. First, used the dredge rate and bucket size information from Phase 1 and RM 10.9 to perform a linear regression analysis to find the production rate in CY/HOUR for a 3- and 5-CY bucket (35 and 42 CY/HOUR, respectively). Assumed land-based removal has the same rate as the 3-CY dredge bucket. Then, used all three removals above to perform linear regression analysis of hourly dredge rate and cost per cubic yard. Cost ($/CY) = -0.6653 * (Rate [CY/HOUR]) + 86.675. Applied a nominal 8.45% escalation to represent inflation rate. Assumed a 30% escalation factor to land-based dredging, to account for added cost of construction haul roads and access issues.
Medium 5 CY Dredge	CY	184,068	$ 65	$ 11,964,443	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
Land-Based	CY	30,075	$ 90	$ 2,706,766	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
			Subtotal	**$ 29,039,484**	See Design Criteria in Appendix A.	
Debris Removal	DY	671	$ 3,880	**$ 2,604,415**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Actual cost of debris management and environmental protection was $144,500 and total number of dredging days was 40. Adjusted to 2019 dollars with inflation.
Bathymetric Verification Survey	DY	750	$ 5,600	**$ 4,198,550**	See Design Criteria in Appendix A.	Daily bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC). Consistent with the Lower 8.3-Mile ROD, which assumes the surveyors can complete 1 RM per day or 30 acres/day (8-hour day). Includes verification surveys performed before dredging, after dredging, and after each layer of cap material is placed. Includes labor and equipment.

Table G-3c. Alternative 4 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Water Quality Monitoring	DY	750	$ 11,000	**$ 8,247,151**	See Design Criteria in Appendix A.	Based on project experience, consistent with Lower 8.3-Mile ROD (USEPA 2016). Assumes intensive sampling to support completion certification.
Additional Construction Performance Monitoring	YR	5	$ 1,000,000	**$ 5,000,000**	See Design Criteria in Appendix A.	Based on project experience. May include air quality, sediment, and/or biological monitoring. Lab costs are included.
Monitoring Reporting	YR	5	$ 150,000	**$ 750,000**	See Design Criteria in Appendix A.	Based on project experience.
Barge Unloading/Material Handling	CY	419,405	$ 15	**$ 6,253,323**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Dredging and delivery cost is listed as $1,137,000 total. The total dredged CY for the RM 10.9 removal is 15,742 CY (Table 2-1). Assume 20% of dredging and delivery cost is barge unloading/material handling.
			Subtotal Dredging	**$ 59,024,896**		

Notes:
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LF = linear feet
LS = lump sum
ROD = Record of Decision
YR = year

Table G-3d. Alternative 4 DIRECT CAPITAL COSTS, Capping
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	%	5	$ 20,856,991	**$ 1,042,850**		Based on project experience. Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Material Purchase and Delivery	LS	1				
Sand	CY	252,975	$ 30	$ 7,627,200	Sand is 75% of cap material volume. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Armor/Stone	CY	84,325	$ 36	$ 3,058,469	Armor/stone is conservatively assumed to be 25% of cap material volume. See Design Criteria in Appendix A.	RS Means 2019 030513251050: Aggregate, stone, 3/4" to 1-1/2".
Shoal Habitat Reconstruction Material	CY	82,104	$ 71	$ 5,868,003	Material is 40% (one-foot-thick layer) of cap volume in of shoals. See Design Criteria in Appendix A.	Based on actual unit cost for habitat reconstruction material from the Thea Foss Waterway remediation, found in the Slip 4 Early Action Area 100% Design Submittal Design Analysis Report - Appendix G. Cost Estimate Back-up, Unit Costs (Actuals) Table. Of three reported actual unit costs, selected the most conservative (Thea Foss Waterway - Head) which is $38/TN. Assuming 1 CY habitat material = 1.5 TN, unit cost per cubic yard is $57/TN in 2006 dollars. Added escalation factor to convert to 2019 dollars.
			Subtotal	**$ 16,553,673**		
Onsite Material Handling & Placement	CY	419,405	$ 50	**$ 20,856,991**	See Design Criteria in Appendix A.	See backup for Sand.
Residual Management	LS	1				
Material Purchase and Delivery	CY	16,776	$ 30	$ 505,802	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
Material Placement	CY	16,776	$ 50	$ 834,280	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
			Subtotal	**$ 1,340,082**		
			Subtotal Capping	**$ 39,793,595**		

Notes:
CY = cubic yard
LS = lump sum

Table G-3e. Alternative 4 DIRECT CAPITAL COSTS, Dredged Material Processing
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Sediment Processing at Commercial Facility	CY	419,405	$ 160	**$ 67,104,736**	See Design Criteria in Appendix A.	Based on vendor communication with Clean Earth, and project experience assuming stabilization/solidification treatment similar to RM 10.9 removal action. Includes barge dewatering. Estimated sediment processing alone at $60 - $94/TON, converting to $76-$119/CY based on site characteristics (i.e. sediment density estimated at 1.27 TON/CY). Selected $100/CY as nominal mid-range value. Cost did not include barge dewatering. Barge dewatering assumed to be an additional 60% of sediment processing cost, based on engineering judgment. Considered Sediment Processing Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018) of $195/CY as an upper limit to sediment processing cost for a smaller project.
	Subtotal Dredged Material Processing			**$ 67,104,736**		

Notes:
CY = cubic yard
LS = lump sum
YR = year

Table G-3f. Alternative 4 DIRECT CAPITAL COSTS, Transportation & Disposal
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Transportation & Disposal - Subtitle C	CY	419,405	$ 244	**$ 102,334,723**	See Design Criteria in Appendix A.	Transportation and Disposal - Subtitle C includes transport of debris and sediment. Transportation & Disposal to Subtitle C and Barge dewatering Efflent combined unit costs are based on the Transportation & Disposal cost in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018), which was $5,230,000 for 15,742 CY of in-place sediment, or $332/CY sediment. This cost included dewatered sediment transportation and disposal at a Subtitle C landfill and transportation and disposal of the barge dewatering effluent to a water treatment plant in Baltimore. The same total was assumed, which considers both economies of scale and cost increases from 2013 to 2019. These costs have been distributed in alignment with the LPR Phase I Removal Action Final Construction report (text and Appendix C) (2013) - Transportation and Disposal cost of $10.12MM for 41,434 CY of in-place sediment (Table 3-1). As above, the same total was assumed, which considers both economies of scale and cost increases from 2012 to 2019. The unit cost is $244/CY for transportation and disposal of sediment at a subtitle C facility. The transportation & disposal of the barge dewatering effluent is estimated to be the difference between $332/CY and $244/CY at $88/CY, to retain the same overall cost.
Transportation & Disposal - Barge Dewatering Effluent	CY	419,405	$ 88	**$ 36,907,605**	See Design Criteria in Appendix A.	Includes barge effluent water transport and treatment. See backup for Transportation and Disposal - Subtitle C.
Disposal Testing	LS	1				
TCLP Waste Characterization	EA	148	$ 1,000	$ 148,398	One test for every 5,000 CY of dewatered material.	Includes analysis, shipping, and data validation costs, based on project experience. Based on vendor communication with ALS: TCLP analytical cost is $840/sample, shipping is $130/cooler, and data validation is about $134/sample, based on internal rates. Assume 4 samples per cooler.
Paint Filter Tests	EA	148	$ 25	$ 3,710	One test for every 5,000 CY of dewatered material.	Based on Lower 8.3-Mile ROD (USEPA 2016).
			Subtotal	**$ 152,108**		
			Subtotal Transportation & Disposal	**$ 139,394,436**		

Notes:
CY = cubic yard
LS = lump sum
TCLP = toxicity characteristic leaching procedure
TN = ton

Table G-3g. Alternative 4 INDIRECT CAPITAL COSTS
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**		Backup provided in Appendix G, Section 2: Basis of Estimates. Pre-design investigation (PDI) includes sediment sampling on 80-ft centers and estimated costs for supporting surveys (e.g., debris, habitat, and cultural surveys) and testing (e.g., sediment processing and water).
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**		Approximately 6% of TDCC, based on best professional judgement and project experience; not expected to vary with alternatives. Includes services to design the remedial action, design analysis, preliminary/intermediate/final design, plans & specifications, and cost estimate. This item does not include pre-design sampling or surveys.
Coordination with Agency/Stakeholders	%	0.5	TDCC	**$ 1,924,500**		Based on project experience.
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 26,943,000**		Based on project experience and EPA guidance (USEPA 2000). Includes agency oversight during construction, confirmation sampling, community air monitoring, services to manage construction or installation of remedial action, excluding any similar services provided as part of construction activities; includes submittal review, change order review, design modifications, construction observation, construction survey, construction schedule tracking, QA/QC documentation, OMM manual, and record drawings.
Project Management	%	5	TDCC	**$ 19,245,000**		Based on project experience and EPA guidance (USEPA 2000). Includes services to support construction or installation of remedial action, not specific to remedial design or construction management; includes planning, community relations, bid/contract administration, cost and performance reporting, permitting, legal, and construction completion report.
			Subtotal Indirect Capital Costs	**$ 119,112,500**		

Notes:
LS = lump sum
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
OMM = operation, maintenance, and monitoring
PDI = Pre-design Investigation
QA/QC = quality assurance and quality control
TDCC = total direct capital costs

Table G-3h. Alternative 4 ANNUAL OPERATION, MAINTENANCE, AND MONITORING COSTS
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

					Notes	
Task	Units	Quantity	Unit Price	Total Cost	Quantity	Unit Price
Reporting	YR	1	$ 100,000	**$ 100,000**	Includes annual tissue and water quality monitoring reports.	Estimated based on project experience
Institutional Controls	YR	1	$ 525,000	**$ 525,000**	Includes informational devices, propriety controls, and enforcement tools.	Estimated based on project experience
Technical Support	YR	1	$ 90,000	**$ 90,000**	Represents OMM portion of agency oversight, project coordination.	Calculated based on approximately 15% of OMM costs before contingency, based on EPA guidance (USEPA 2000).
		Subtotal Annual OMM		**$ 715,000**		

Notes:

OMM = operation, maintenance, and monitoring

RD/RA = remedial design/remedial action

YR = year

Table G-3i. Alternative 4 PERIODIC COSTS
2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**	14 events occur, annually for the first 10 years after the end of construction, and then in years 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates. Includes biota sampling, sediment profile imaging survey, and water quality monitoring.
Cap Monitoring	EVENT	7	$ 62,400	**$ 436,800**	7 events occur, in years 5, 10, 15, 20, 25, 30, and 35 after the start of construction.	Estimated based on project experience; cap monitoring will include bathymetric surveys and chemical monitoring. Based on footprint area of alternative monitored; assumes $600/acre for monitoring work.
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Estimated based on project experience. Surveys performed opportunistically (e.g., after high flow event) over entire reach. Bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC).
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**	1 event occurs, in year 5 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Cap Maintenance (Year 0 through Year 15)	EVENT	3			3 events occur, in years 5, 10, and 15 after the start of construction.	
Mobilization/Demobilization	%	5	$ 1,042,850	$ 52,142		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	20,970	$ 30	$ 632,252	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Onsite Material Handling & Placement	CY	20,970	$ 50	$ 1,042,850	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See backup for Material Purchase and Delivery.
			Subtotal	**$ 1,727,244**		
Cap Maintenance (Year 16 through Year 35)	EVENT	4			4 events occur, in years 20, 25, 30, and 35 after the start of construction.	
Mobilization/Demobilization	%	5	$ 521,425	$ 26,071		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	10,485	$ 30	$ 316,126	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
Onsite Material Handling & Placement	CY	10,485	$ 50	$ 521,425	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
			Subtotal	**$ 863,622**		
			Subtotal Periodic Costs	**$ 25,473,022**		

Notes:
CY = cubic yard
LPR = Lower Passaic River

Table G-4a. Alternative 5 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost[a]
KEY ASSUMPTIONS				
Contingency[b]	%	25		
Discount rate, i[c]	%	7.0		
DIRECT CAPITAL COSTS[d]				
Construction Staging Facility				
Staging Area Land Purchase/Lease	AC	5	$ 200,000	$ 1,000,000
Support Facilities	YR	3	$ 310,000	$ 1,000,000
Subtotal Construction Staging Facility				**$ 2,000,000**
Dredging				
Mobilization/Demobilization[e]	LS	1	$ 912,600	$ 900,000
Protections & Controls	LS	1	$ 1,376,000	$ 1,400,000
Mechanical Dredging[f]	CY	250,067	$ 68	$ 17,100,000
Debris Removal	DY	401	$ 3,880	$ 1,600,000
Bathymetric Verification Survey	DY	480	$ 5,600	$ 2,700,000
Water Quality Monitoring	DY	480	$ 11,000	$ 5,300,000
Additional Construction Performance Monitoring	YR	4	$ 1,000,000	$ 4,000,000
Monitoring Reporting	YR	4	$ 150,000	$ 600,000
Barge Unloading/Material Handling	CY	250,067	$ 15	$ 3,700,000
Subtotal Dredging				**$ 37,300,000**
Capping				
Mobilization/Demobilization[e]	LS	1	$ 621,800	$ 600,000
Material Purchase & Delivery[g]	CY	250,067	$ 41	$ 10,200,000
On-Site Material Handling & Placement	CY	250,067	$ 50	$ 12,500,000
Residual Management	LS	1	$ 799,000	$ 800,000
Subtotal Capping				**$ 24,100,000**
Dredged Material Processing				
Sediment Processing at Commercial Facility	CY	250,067	$ 160	$ 40,000,000
Subtotal Dredged Material Processing				**$ 40,000,000**
Transportation & Disposal				
Transportation & Disposal - Subtitle C	CY	250,067	$ 244	$ 61,000,000
Transportation & Disposal - Barge Dewatering Effluent	CY	250,067	$ 88	$ 22,000,000
Disposal Testing	LS	1	$ 90,700	$ 100,000
Subtotal Transportation & Disposal				**$ 83,100,000**
SUBTOTAL DIRECT CAPITAL COSTS				**$ 186,500,000**
CONTINGENCY (25%)				**$ 46,600,000**
TOTAL DIRECT CAPITAL COSTS				**$ 233,100,000**

Table G-4a. Alternative 5 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost[a]
INDIRECT CAPITAL COSTS[d]				
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**
Coordination with Agencies/Stakeholders	%	0.5	TDCC	**$ 1,200,000**
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 16,300,000**
Project Management	%	5	TDCC	**$ 11,700,000**
TOTAL INDIRECT CAPITAL COSTS				**$ 100,200,000**
TOTAL CAPITAL COSTS				
TOTAL CAPITAL COSTS				**$ 333,300,000**
ANNUAL OMM COSTS[d]				
Reporting[h]	YR	1	$ 100,000	**$ 100,000**
Institutional Controls[h]	YR	1	$ 525,000	**$ 500,000**
Technical Support[h]	YR	1	$ 90,000	**$ 100,000**
SUBTOTAL ANNUAL OMM COSTS				**$ 700,000**
CONTINGENCY (25%)				**$ 200,000**
TOTAL ANNUAL OMM COSTS				**$ 900,000**
PERIODIC COSTS[d]				
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**
Cap Monitoring	EVENT	7	$ 37,200	**$ 300,000**
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**
Cap Maintenance (Year 0 through Year 15)	EVENT	3	$ 1,029,900	**$ 3,100,000**
Cap Maintenance (Year 16 through Year 35)	EVENT	4	$ 514,900	**$ 2,100,000**
SUBTOTAL PERIODIC COSTS				**$ 37,300,000**
CONTINGENCY (25%)				**$ 9,300,000**
TOTAL PERIODIC COSTS				**$ 46,600,000**

Table G-4a. Alternative 5 Cost Estimate Summary
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost[a]
PRESENT WORTH COSTS (7% Discount; T=30 Years After Construction)				
Capital Costs				$ 294,400,000
Annual OMM				$ 8,300,000
Periodic Costs				$ 18,500,000
TOTAL PRESENT WORTH				**$ 321,200,000**

Notes:

AC = acre
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
LS = lump sum
OMM = operation, maintenance, and monitoring
ROD = Record of Decision
TDCC = total direct capital costs
TN = ton
YR = year

[a]Approximate totals are rounded to the nearest $100,000.

[b]15% scope contingency and 10% bid contingency. These contingencies are near baseline values specified in the EPA cost guidance document (USEPA 2000).

[c]Per EPA cost guidance (USEPA 2000), discount rate is 7%.

[d]This estimate represents costs with +50/-30% accuracy. All assumptions and costs are only for feasibility study purposes and are subject to refinement in the ROD and during remedial design.

[e]5% of material and installation costs; see Tables G-4c and G-4d sheet for details.

[f]Unit cost reflects weighted average of estimated unit costs for each bucket size/type (3 CY, 5 CY, and land-based) by their proportional use. See Table G-4c for details.

[g]Unit cost reflects weighted average of estimated unit costs for each material type (sand, armor/stone, and shoal habitat reconstruction material) by their estimated proportional use. See Table G-4d for details.

[h]Annual cost starts in Year 5 and continues until 30 years after construction.

Table G-4b. Alternative 5 DIRECT CAPITAL COSTS, Construction Staging Facility
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Staging Area Land Purchase/Lease	AC	5	$ 200,000	**$ 1,000,000**	Property used for contractor trailers, sample processing, equipment storage, and parking.	Based on average purchase price of selected potentially vacant sites from NY/NJ tax records. Properties were selected based on availability, proximity, size, accessibility, and upgrade requirements in the 2015 Draft Lower Passaic River Feasibility Study (Appendix C). Some properties were not included in the cost analysis because cost data was unavailable. A few properties were excluded because they had high, outlying unit costs. Costs are accurate to 2018. Selected locations were: Block 586, Lot 8, Linden NJ ($3.57/SF) Block 587, Lot 8, Linden NJ ($9.31/SF) Block 1, Lot 9, Kearny, NJ ($1.77/SF) Block 1, Lot 10, Kearny, NJ ($1.84/SF) Block 1, Lot 12, Kearny, NJ ($2.03/SF) Block 1, Lot 12.01, Kearny, NJ ($1.22/SF) Block 5014, Lot 1.01, Newark , NJ ($5.00/SF) Block 5070, Lot 3, Newark, NJ ($9.69/SF) Block 5070, Lot 5, Newark, NJ ($8.04/SF) Average unit cost is $4.72/SF or about $200,000/AC. Assumes the parcel will be in a condition that permits immediate installation of support facilities. Alternatively, this land could be leased.
Support Facilities	YR	3	$ 310,000	**$ 977,913**	See Design Criteria in Appendix A.	RS Means 2019; Reference numbers: 015213200550, Office trailer, furnished, rent per month, 50' x 12', excl. hookups. 015213400100, Field office expense, office equipment rental, average. 015213400120, Field office expense, office supplies, average. 015213201250, Storage boxes rent per month, 20' x 8'. 015113800700, Temporary utilities, temporary construction water bill per month, average. 015213400140, Field office expense, telephone bill; average bill/month, incl. long distance. 015113800600, Temporary utilities, power for job duration incl elevator etc., minimum. Per 100 square feet of floor. 015433403000, Rent space heaters oil or electric 100 MBH. 015213400160, Field office expense, field office lights and HVAC. 015433406410, Rent toilet, portable chemical. 323113200920, Fence, chain link industrial, galvanized steel, 6 ga. wire, 2-1/2" posts at 10' OC, 8' high, includes excavation, in concrete, excludes barbed wire. 323113205090, Fence, chain link industrial, double swing gates, 8' high, 20' opening, includes excavation, posts, and hardware in concrete. 015632500100, Watchman, security service, uniformed person, monthly bases, max ($58.05/HR). Car rental unit cost from www.avis.com.
			Subtotal Construction Staging Facility	**$ 1,977,913**		

Notes:
AC = acre
YR = year

Table G-4c. Alternative 5 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	LS	1				
Dredging Equipment	%	5	$ 17,052,113	$ 852,606		Based on project experience. Percent of mechanical dredging costs including land-based dredging costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Critical Structure Protection Equipment	%	5	$ 1,200,000	$ 60,000		Based on project experience. Percent of critical structure protection costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
			Subtotal	**$ 912,606**		
Protections & Controls	LS	1				
Turbidity Control	LF	4,000	$ 44	$ 176,000	Each dredge system will utilize 1,000 LF of turbidity curtain. Assume that one spare set is always available and a set must be fully replaced each year.	Includes purchase, installation, and removal of silt curtain. Based on vendor communication with EnviroUSA (among other similar vendors): material is $25.95/LF, lump sum of $5774 for delivery of 1000 LF. Assume 16-hour installation x 2 installers (at $120/HR) on a boat ($2000 lump sum) to install 1000 LF. Assume the same for removal. Assume additional 10% of the material cost for maintenance during lifetime of one year. Unit cost of turbidity curtain per LF = $25.95/LF * 1.1 + $5.77/LF + (((2 installers * 16 hours * 2 events * $120) + $2,000) / 1,000 LF).
Critical Structure/Utility Protection	LS	1	$ 1,200,000	$ 1,200,000		This is a placeholder value, estimated based on project experience and the extent of potential critical structures and utilities in the upper 9-miles of the LPR. Design will seek to minimize reliance on protection.
			Subtotal	**$ 1,376,000**		
Mechanical Dredging	LS	1				
Small 3 CY Dredge	CY	142,220	$ 70	$ 9,955,382	See Design Criteria in Appendix A.	Multiple completed dredging projects were considered; three were selected as both being the most similar and having all the relevant information available. 1. LPR Phase I Removal Action Final Construction Report, (Main Text and Appendix C) (2013): Dredging unit cost was $58/CY (including mobilization/demobilization) for 41,434 CY for one 5-CY environmental bucket, with a dredge rate of 500 CY/DAY, working 12-hour days. 2. Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018): Dredging cost was $1,137,000 (including delivery) for 15,742 CY for one 2.6-CY environmental bucket, with a dredge rate of 394 CY/DAY. Estimated reduction to cost for delivery means unit cost is $65/CY. 3. Reynolds Metals Massena MCSS Database Release (2004): Dredging cost was $5,000,000 for 85,600 CY for two 5-1/2 and one 2-1/2 CY bucket environmental bucket, with a dredge rate of 873 CY/DAY working 20-hour days. Unit cost equals $58/CY. First, used the dredge rate and bucket size information from Phase 1 and RM 10.9 to perform a linear regression analysis to find the production rate in CY/HOUR for a 3- and 5-CY bucket (35 and 42 CY/HOUR, respectively). Assumed land-based removal has the same rate as the 3-CY dredge bucket. Then, used all three removals above to perform linear regression analysis of hourly dredge rate and cost per cubic yard. Cost ($/CY) = -0.6653 * (Rate [CY/HOUR]) + 86.675. Applied a nominal 8.45% escalation to represent inflation rate. Assumed a 30% escalation factor to land-based dredging, to account for added cost of construction haul roads and access issues.
Medium 5 CY Dredge	CY	104,380	$ 65	$ 6,784,679	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
Land-Based	CY	3,467	$ 90	$ 312,053	See Design Criteria in Appendix A.	See backup for Small 3 CY dredge.
			Subtotal	**$ 17,052,113**	See Design Criteria in Appendix A.	
Debris Removal	DY	401	$ 3,880	**$ 1,556,134**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Actual cost of debris management and environmental protection was $144,500 and total number of dredging days was 40. Adjusted to 2019 dollars with inflation.
Bathymetric Verification Survey	DY	480	$ 5,600	**$ 2,685,567**	See Design Criteria in Appendix A.	Daily bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC). Consistent with the Lower 8.3-Mile ROD, which assumes the surveyors can complete 1 RM per day or 30 acres/day (8-hour day). Includes verification surveys performed before dredging, after dredging, and after each layer of cap material is placed. Includes labor and equipment.

Table G-4c. Alternative 5 DIRECT CAPITAL COSTS, Dredging
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Water Quality Monitoring	DY	480	$ 11,000	**$ 5,275,221**	See Design Criteria in Appendix A.	Based on project experience, consistent with Lower 8.3-Mile ROD (USEPA 2016). Assumes intensive sampling to support completion certification.
Additional Construction Performance Monitoring	YR	4	$ 1,000,000	**$ 4,000,000**	See Design Criteria in Appendix A.	Based on project experience. May include air quality, sediment, and/or biological monitoring. Lab costs are included.
Monitoring Reporting	YR	4	$ 150,000	**$ 600,000**	See Design Criteria in Appendix A.	Based on project experience.
Barge Unloading/Material Handling	CY	250,067	$ 15	**$ 3,728,494**	See Design Criteria in Appendix A.	Based on professional judgment, considering actual construction costs in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018). Dredging and delivery cost is listed as $1,137,000 total. The total dredged CY for the RM 10.9 removal is 15,742 CY (Table 2-1). Assume 20% of dredging and delivery cost is barge unloading/material handling.
			Subtotal Dredging	**$ 37,186,136**		

Notes:
CY = cubic yard
DY = day
EPA = U.S. Environmental Protection Agency
LF = linear feet
LS = lump sum
ROD = Record of Decision
YR = year

Table G-4d. Alternative 5 DIRECT CAPITAL COSTS, Capping
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Mobilization/Demobilization	%	5	$ 12,435,815	**$ 621,791**		Based on project experience. Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles due to seasonal shutdown.
Material Purchase and Delivery	LS	1				
Sand	CY	144,884	$ 30	$ 4,368,255	Sand is 75% of cap material volume. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Armor/Stone	CY	48,295	$ 36	$ 1,751,648	Armor/stone is conservatively assumed to be 25% of cap material volume. See Design Criteria in Appendix A.	RS Means 2019 030513251050: Aggregate, stone, 3/4" to 1-1/2".
Shoal Habitat Reconstruction Material	CY	56,888	$ 71	$ 4,065,778	Material is 40% (one-foot-thick layer) of cap volume in of shoals. See Design Criteria in Appendix A.	Based on actual unit cost for habitat reconstruction material from the Thea Foss Waterway remediation, found in the Slip 4 Early Action Area 100% Design Submittal Design Analysis Report - Appendix G. Cost Estimate Back-up, Unit Costs (Actuals) Table. Of three reported actual unit costs, selected the most conservative (Thea Foss Waterway - Head) which is $38/TN. Assuming 1 CY habitat material = 1.5 TN, unit cost per cubic yard is $57/TN in 2006 dollars. Added escalation factor to convert to 2019 dollars.
			Subtotal	**$ 10,185,681**		
Onsite Material Handling & Placement	CY	250,067	$ 50	**$ 12,435,815**	See Design Criteria in Appendix A.	See backup for Sand.
Residual Management	LS	1				
Material Purchase and Delivery	CY	10,003	$ 30	$ 301,580	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
Material Placement	CY	10,003	$ 50	$ 497,433	20 percent of the dredge area will require placement of a nominal 6 inch layer to mitigate dredge residuals that have settled outside the remediation footprint. Actual area will be determined through quality assurance sampling during remedial construction.	See backup for Sand.
			Subtotal	**$ 799,013**		
			Subtotal Capping	**$ 24,042,301**		

Notes:
CY = cubic yard
LS = lump sum

Table G-4e. Alternative 5 DIRECT CAPITAL COSTS, Dredged Material Processing
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Sediment Processing at Commercial Facility	CY	250,067	$ 160	**$ 40,010,667**	See Design Criteria in Appendix A.	Based on vendor communication with Clean Earth, and project experience assuming stabilization/solidification treatment similar to RM 10.9 removal action. Includes barge dewatering. Estimated sediment processing alone at $60 - $94/TON, converting to $76-$119/CY based on site characteristics (i.e. sediment density estimated at 1.27 TON/CY). Selected $100/CY as nominal mid-range value. Cost did not include barge dewatering. Barge dewatering assumed to be an additional 60% of sediment processing cost, based on engineering judgment. Considered Sediment Processing Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018) of $195/CY as an upper limit to sediment processing cost for a smaller project.
	Subtotal Dredged Material Processing			**$ 40,010,667**		

Notes:
CY = cubic yard
LS = lump sum
YR = year

Table G-4f. Alternative 5 DIRECT CAPITAL COSTS, Transportation & Disposal
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Transportation & Disposal - Subtitle C	CY	250,067	$ 244	**$ 61,016,267**	See Design Criteria in Appendix A.	Transportation and Disposal - Subtitle C includes transport of debris and sediment. Transportation & Disposal to Subtitle C and Barge dewatering Efflent combined unit costs are based on the Transportation & Disposal cost in Table 4-1 of the LPR RM 10.9 Removal Final Construction Report (2018), which was $5,230,000 for 15,742 CY of in-place sediment, or $332/CY sediment. This cost included dewatered sediment transportation and disposal at a Subtitle C landfill and transportation and disposal of the barge dewatering effluent to a water treatment plant in Baltimore. The same total was assumed, which considers both economies of scale and cost increases from 2013 to 2019. These costs have been distributed in alignment with the LPR Phase I Removal Action Final Construction report (text and Appendix C) (2013) - Transportation and Disposal cost of $10.12MM for 41,434 CY of in-place sediment (Table 3-1). As above, the same total was assumed, which considers both economies of scale and cost increases from 2012 to 2019. The unit cost is $244/CY for transportation and disposal of sediment at a subtitle C facility. The transportation & disposal of the barge dewatering effluent is estimated to be the difference between $332/CY and $244/CY at $88/CY, to retain the same overall cost.
Transportation & Disposal - Barge Dewatering Effluent	CY	250,067	$ 88	**$ 22,005,867**	See Design Criteria in Appendix A.	Includes barge effluent water transport and treatment. See backup for Transportation and Disposal - Subtitle C.
Disposal Testing	LS	1				
TCLP Waste Characterization	EA	88	$ 1,000	$ 88,468	One test for every 5,000 CY of dewatered material.	Includes analysis, shipping, and data validation costs, based on project experience. Based on vendor communication with ALS: TCLP analytical cost is $840/sample, shipping is $130/cooler, and data validation is about $134/sample, based on internal rates. Assume 4 samples per cooler.
Paint Filter Tests	EA	88	$ 25	$ 2,212	One test for every 5,000 CY of dewatered material.	Based on Lower 8.3-Mile ROD (USEPA 2016).
			Subtotal	**$ 90,680**		
			Subtotal Transportation & Disposal	**$ 83,112,813**		

Notes:
CY = cubic yard
LS = lump sum
TCLP = toxicity characteristic leaching procedure
TN = ton

Table G-4g. Alternative 5 INDIRECT CAPITAL COSTS
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Pre-Design Investigations	LS	1	$ 50,000,000	**$ 50,000,000**		Backup provided in Appendix G, Section 2: Basis of Estimates. Pre-design investigation (PDI) includes sediment sampling on 80-ft centers and estimated costs for supporting surveys (e.g., debris, habitat, and cultural surveys) and testing (e.g., sediment processing and water).
Remedial Design	LS	1	$ 21,000,000	**$ 21,000,000**		Approximately 6% of TDCC, based on best professional judgement and project experience; not expected to vary with alternatives. Includes services to design the remedial action, design analysis, preliminary/intermediate/final design, plans & specifications, and cost estimate. This item does not include pre-design sampling or surveys.
Coordination with Agency/Stakeholders	%	0.5	TDCC	**$ 1,165,500**		Based on project experience.
Construction Management/Construction Quality Assurance	%	7	TDCC	**$ 16,317,000**		Based on project experience and EPA guidance (USEPA 2000). Includes agency oversight during construction, confirmation sampling, community air monitoring, services to manage construction or installation of remedial action, excluding any similar services provided as part of construction activities; includes submittal review, change order review, design modifications, construction observation, construction survey, construction schedule tracking, QA/QC documentation, OMM manual, and record drawings.
Project Management	%	5	TDCC	**$ 11,655,000**		Based on project experience and EPA guidance (USEPA 2000). Includes services to support construction or installation of remedial action, not specific to remedial design or construction management; includes planning, community relations, bid/contract administration, cost and performance reporting, permitting, legal, and construction completion report.
			Subtotal Indirect Capital Costs	**$ 100,137,500**		

Notes:
LS = lump sum
EPA = U.S. Environmental Protection Agency
LPR = Lower Passaic River
OMM = operation, maintenance, and monitoring
PDI = Pre-design Investigation
QA/QC = quality assurance and quality control
TDCC = total direct capital costs

Table G-4h. Alternative 5 ANNUAL OPERATION, MAINTENANCE, AND MONITORING COSTS
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Reporting	YR	1	$ 100,000	**$ 100,000**	Includes annual tissue and water quality monitoring reports.	Estimated based on project experience
Institutional Controls	YR	1	$ 525,000	**$ 525,000**	Includes informational devices, propriety controls, and enforcement tools.	Estimated based on project experience
Technical Support	YR	1	$ 90,000	**$ 90,000**	Represents OMM portion of agency oversight, project coordination.	Calculated based on approximately 15% of OMM costs before contingency, based on EPA guidance (USEPA 2000).
		Subtotal Annual OMM		**$ 715,000**		

Notes:

OMM = operation, maintenance, and monitoring

RD/RA = remedial design/remedial action

YR = year

Table G-4i. Alternative 5 PERIODIC COSTS
2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL

Task	Units	Quantity	Unit Price	Total Cost	Notes: Quantity	Notes: Unit Price
Long-Term Monitoring	EVENT	14	$ 1,100,000	**$ 15,400,000**	14 events occur, annually for the first 10 years after the end of construction, and then in years 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates. Includes biota sampling, sediment profile imaging survey, and water quality monitoring.
Cap Monitoring	EVENT	7	$ 37,200	**$ 260,400**	7 events occur, in years 5, 10, 15, 20, 25, 30, and 35 after the start of construction.	Estimated based on project experience; cap monitoring will include bathymetric surveys and chemical monitoring. Based on footprint area of alternative monitored; assumes $600/acre for monitoring work.
Bathymetric and Other Surveys	EVENT	6	$ 150,000	**$ 900,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Estimated based on project experience. Surveys performed opportunistically (e.g., after high flow event) over entire reach. Bathymetric survey cost based on LPR Predesign Current Conditions actual daily cost (Pers. Communication with Anchor QEA, LLC).
Initial Surface Sediment Sampling Event	EVENT	1	$ 3,500,000	**$ 3,500,000**	1 event occurs, in year 5 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Follow-Up Surface Sediment Sampling Events	EVENT	6	$ 2,000,000	**$ 12,000,000**	6 events occur, in years 9, 14, 19, 24, 29, and 34 after the start of construction.	Backup provided in Appendix G, Section 2: Basis of Estimates.
Cap Maintenance (Year 0 through Year 15)	EVENT	3			3 events occur, in years 5, 10, and 15 after the start of construction.	
Mobilization/Demobilization	%	5	$ 621,791	$ 31,090		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	12,503	$ 30	$ 376,976	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	Based on professional judgment, considering LPR Phase I Removal Action Final Construction Report, (Text and Appendix C) (2013), which states the "Backfill of Removal Area" cost is $3,280,000 for 47,849 CY, or about $69/CY capping material. Accounting for inflation, this becomes about $77/CY cap material, rounded up to $80/CY (to account for difficult transport along the Passaic River and placement of habitat sand layer in shoal areas). Cost is broken up into material and placement costs based on $30/CY sand cost found on RS Means 2019 030513250950: Aggregate, sand, washed, for concrete, loaded at the pit, prices per CY, includes material only. The remaining $50/CY is ascribed to material placement costs.
Onsite Material Handling & Placement	CY	12,503	$ 50	$ 621,791	5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See backup for Material Purchase and Delivery.
			Subtotal	**$ 1,029,856**		
Cap Maintenance (Year 16 through Year 35)	EVENT	4			4 events occur, in years 20, 25, 30, and 35 after the start of construction.	
Mobilization/Demobilization	%	5	$ 310,895	$ 15,545		Percent of onsite material handling and placement costs; considers multiple mobilization/demobilization cycles.
Material Purchase and Delivery	CY	6,252	$ 30	$ 188,488	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
Onsite Material Handling & Placement	CY	6,252	$ 50	$ 310,895	2.5 percent of capping materials to be replaced. See Design Criteria in Appendix A.	See Cap Maintenance (Year 0 though Year 15) for backup.
			Subtotal	**$ 514,928**		
			Subtotal Periodic Costs	**$ 21,809,679**		

Notes:
CY = cubic yard
LPR = Lower Passaic River

Table G-5. Summary of Cost Estimates

Alternative	Description	Direct Capital ($M) [a]	Indirect Capital ($M)	Total Capital ($M)	Annual OMM ($M/year) [a,b]	Periodic OMM ($M) [a]	Present Value ($M) [c]
1	No Further Action	0.0	0.0	0.0	0.0	0.0	0.0
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	335	113	448	0.9	50	420
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	357	116	472	0.9	50	441
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	385	119	504	0.9	51	468
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	233	100	333	0.9	47	321

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

M = million

OMM = operation, maintenance, and monitoring

PCB = polychlorinated biphenyl

RAL = remedial action level

SWAC = surface area-weighted average concentration

Estimates represent a feasibility level of accuracy (+50/-30%).

[a] Direct capital, annual OMM, and periodic costs include 25% contingency.

[b] Annual OMM costs are assumed to begin in Year 5 and extend for 30 years after construction is complete.

[c] Discounted at a rate of 7.0%.

Table G-6. Sensitivity Analysis of Cost Estimate Contingency and Discount Rates

Alternative	Description	Discount Rate	Cost ($M) 25% Contingency	Cost ($M) 35% Contingency
1	No Further Action	0.0%	0	0
		1.5%[a]	0	0
		7.0%[b]	0	0
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	0.0%	524	560
		1.5%	494	528
		7.0%	420	448
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	0.0%	549	587
		1.5%	518	553
		7.0%	441	470
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	0.0%	581	622
		1.5%	549	587
		7.0%	468	500
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	0.0%	406	433
		1.5%	381	406
		7.0%	321	341

Notes:

2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
M = million
PCB = polychlorinated biphenyl
RAL = remedial action level
SWAC = surface area-weighted average concentration
Base costs are discounted at 7.0%, with 25% contingency.

[a] Discount rate from the U.S. Office of Management and Budget's Circular A-94 Guideline and Discount Rates for Benefit-Cost Analysis of Federal Programs real interest rates for a 30-year time period (OMB 2018)

[b] Discount rate from USEPA guide to developing and documenting cost estimates during the feasibility study (USEPA 2000)

Table G-7. Sensitivity Analysis of Landfill Type for Disposal

Alternative	Description	Total Present Value ($M) [a]	
		Subtitle C Disposal	Subtitle D Disposal
1	No Further Action	0	0
2	2,3,7,8-TCDD target SWAC = 85 ppt, Total PCB RAL = 1 ppm	420	350
3	2,3,7,8-TCDD target SWAC = 75 ppt, Total PCB RAL = 1 ppm	441	366
4	2,3,7,8-TCDD target SWAC = 65 ppt, Total PCB RAL = 1 ppm	468	387
5	2,3,7,8-TCDD target SWAC = 125 ppt, no Total PCB RAL	321	273

Notes:
2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
M = million
PCB = polychlorinated biphenyl
RAL = remedial action level
SWAC = surface area-weighted average concentration
[a] Discounted at a rate of 7.0%.

Table G-8. Summary of Dredging Technology Cost Sensitivity Evaluation[a]

Project Element	Hydraulic Cost ($M)	Mechanical Cost ($M)
Dredging	42	31
Pipeline/Barge Handling	52	6
Upland Site Preparation	10	2
Processing	62	62
Water Treatment	30	0
Transportation & Disposal	102	129
TOTAL[b]	298	230

Notes:

M = million

[a] Costs are based on Alternative 3.

[b] Total includes cost elements that are dependent on dredge technology.

Attachment G1

Dredging Technology Cost Sensitivity Evaluation

Attachment G1
Dredging Technology Cost Sensitivity Evaluation

Costs associated with hydraulic and mechanical dredging were evaluated to determine how sensitive the overall IR FS cost is to the dredging technology.

Remedy Elements Affected by Dredging Technology

The selection of dredging technologies will impact the total cost estimate for dredging and disposal beyond the dredging equipment costs. The assumptions for hydraulic dredging used in the cost estimate are discussed below.

The cutterhead of a hydraulic dredge entrains a much higher volume of water than a mechanical environmental bucket. Mechanical dredging can yield a dredged material solids content of 80–90 percent relative to the *in situ* sediment solids content (resulting in a predicted 45–50 percent solids content at the LPR), while hydraulic dredging yields a dredged slurry solids content of about 10 percent, although both can vary by application (USEPA 2016). Because of the high water content, transportation and processing of hydraulically dredged slurry is different from that of mechanically dredged material. The typical and most implementable transportation method for hydraulic dredging is a hydraulic pipeline from the dredging location to the processing facility. The IR FS assumption for sediment processing is solidification and stabilization at a commercial facility; however, it is not feasible to solidify/stabilize the hydraulically dredged slurry without dewatering due to the high water content. Therefore, a mechanical dewatering facility and a water treatment plant are assumed to be constructed and operated for hydraulically dredged sediment.

Dredging

The assumed unit cost of hydraulic dredging is $40 per cubic yard (cy), based on similar projects. For the LPR, which is expected to have more debris in the sediment than typical projects where hydraulic dredging was employed such as Fox River, additional debris survey work, initial debris removal, and periodic debris removal by a mechanical dredge are factored into the cost. Mobilization and demobilization costs are assumed to be significantly greater for hydraulic dredging, due to periodic stopping and restarting to clear debris from the work area.

Pipeline/Barge Unloading

Hydraulic pipeline installation, operation, and removal costs were estimated based on the LPR Phase 1 remedy actual costs (Tierra 2013). The costs include the crew, booster pumps, floaters, anchors, and vacuum breakers. The length of the pipe is assumed to be 15 miles, given a processing facility constructed at or near the mouth of the Passaic River. Hydraulic pipelines do not have an associated unloading/material handling cost at the processing facility.

Upland Site Preparation

It is assumed that a land purchase of 12 acres would be required for hydraulic dredging to construct the processing facility. Additional costs are for the berth upgrade for barged debris staging, and the rail siding construction for transportation.

Processing Facility

The civil engineering and construction of the processing facility and water treatment plant are factored into the hydraulic dredging cost estimate. It is assumed that a facility can be constructed within 2 miles of the mouth of the LPR. Costs are based on the LPR Phase 1 actual costs (Tierra 2013) and other similar sites. The size of the processing facility is based on the anticipated dredge rate, which is assumed to be 3,000 cy/day for hydraulic dredging, given an assumed 20 cm pump size (USEPA 2016). Equipment replacement is also factored into the mechanical dewatering processing costs.

Water Treatment

Water treatment costs are included for treatment at a constructed facility. Costs are based on water treatment plant size, which is dependent on the production rate of water. Equipment replacement is also factored into the water treatment plant costs.

Transportation and Disposal

From the constructed processing facility, mechanically dewatered sediment would be transported and disposed of at a permitted disposal facility. Due to the assumption of mechanical dewatering, the resulting effluent water is not included in the transportation and disposal cost.

Cost Sensitivity

Unit costs for hydraulic dredging upland site preparation, processing facility, water treatment, and transportation and disposal were based on recent, similar projects including LPR Phase 1 remedy (Tierra 2013). A detailed cost estimate for these costs is beyond the scope of this sensitivity analysis.

The cost sensitivity analysis was performed for Alternative 3. Table G-8 presents a cost comparison of the major elements of the remedy that are dependent on dredging technology selection. Including all direct and indirect capital, OMM, and periodic costs, discount rate and contingency, Alternative 3 is 16 percent more expensive with hydraulic dredging technology than with mechanical.

References

Tierra. 2013. Final construction report Lower Passaic River Study Area Phase I removal action, March. Tierra Solutions, Inc., East Brunswick, NJ.

USEPA. 2016. Lower eight miles of the Lower Passaic River, part of the Diamond Alkali Superfund site, Essex and Hudson Counties, New Jersey. Superfund Record of Decision. U.S. Environmental Protection Agency Region 2, New York, NY.

Appendix H
Interim Remedy Completion Evaluation Framework

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FIGURES

Figure 1 Distribution of Post-IR Surface 2,3,7,8-TCDD SWACs for 100 Conditional Simulations Based on a RAL of 205 ng/kg

Figure 2 Decision Tree for IR Completion Determination

ATTACHMENTS

Attachment 1 Methodology for Establishing the Y Values

ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
BMP	best management practice
DMU	decision management unit
FS	Feasibility Study
IR	Interim Remedy
LCL	lower confidence limit
LOE	Line of Evidence
mg/kg	milligrams per kilogram
ng/kg	nanograms per kilogram
PCB	polychlorinated biphenyl
PDI	Pre-Design Investigation
ppm	parts per million
ppt	parts per trillion
RAL	Remedial Action Level
RAO	Remedial Action Objective
RM	river mile
SWAC	surface-area weighted average concentration
UCL	upper confidence limit
USEPA	U.S. Environmental Protection Agency

1 Introduction

1.1 Overview

This Interim Remedy (IR) has two Remedial Action Objectives (RAOs) for source control against which its completion will be assessed (see Section 3 of the IR Feasibility Study [FS] for a discussion of the RAOs). Embodied in the RAOs are objectives to control sediment sources that are inhibiting recovery and attain river mile (RM) 8.3 to RM 15 surface-area weighted average concentrations (SWACs) of no greater than 85 nanograms per kilogram (ng/kg) for 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and 0.46 milligrams per kilogram (mg/kg) for total polychlorinated biphenyls (PCBs).

Control of sediment sources will be accomplished by: 1) remediating sediments with surface layer 2,3,7,8-TCDD concentrations at or above a Remedial Action Level (RAL) established to achieve the selected remedy SWAC design target or with surface layer (top 6 inch) total PCB concentrations of 1 mg/kg or higher; and 2) remediating sediments vulnerable to erosion of 6 inches or more and having subsurface[1] total PCB concentrations of 2 mg/kg or higher or 2,3,7,8-TCDD concentrations at or above two times[2] the RAL established to achieve the selected remedy SWAC target.

Successful source control requires accurate mapping of total PCB and 2,3,7,8-TCDD concentrations in sediment, delineating remediation areas in a manner that ensures sediments meeting remediation criteria are targeted, and carefully implementing remediation to address the target areas while minimizing resuspension and redistribution of sediments.

This IR will be deemed successful and complete if it achieves the RAO SWAC goals. Assessing achievement of SWAC goals will rely on interpreting post-IR sediment data, which will not yield a precise estimate of SWAC because of the expected variability of concentrations. One illustration of uncertainty driven by that variability is the uncertainty of the 2,3,7,8-TCDD SWAC that results from addressing sources that are defined as sediments with concentrations at or above the FS Alternative 3 RAL of 205 ng/kg. Across the 100 maps of concentration developed using conditional simulation (see Appendix B), SWACs consistent with addressing sources could be as low as 58 ng/kg or as high as 89 ng/kg (Figure 1). The uncertainty inherent in the SWAC estimates is tolerable because, while the SWAC goals represent concentrations that demonstrate RAO attainment, they do not represent absolute thresholds for when sources would be adequately controlled or when long-term recovery would be adequately accelerated by an IR. Pre-design Investigation (PDI) data will likely reduce uncertainties and a balance between SWAC precision and post-IR confirmation sampling sample size

[1] Analyses to date indicate the relevant subsurface interval is 0.5 to 1.5 feet below the bed surface; the relevant depths will be redetermined using additional pre-design bathymetric, side-scan sonar, and chemistry data.

[2] This multiplier has been used for the IR FS. The multiplier to be used in IR Design will be established during the design (and will be between one and a maximum of two).

will be sought. This balance will be judged to be adequate when the rates of false (i.e., false negative and false positive) post-IR decisions are suitably controlled.

The statistical assessment of post-IR sediment concentrations is the first line of evidence in determining IR completion. If it fails to demonstrate success in achieving an acceptable level of equivalency to the RAO SWAC goals, the IR can still be deemed complete if effective source control is indicated by a weight of evidence approach using other lines of evidence (LOEs).

Before the post-IR sediment data are collected, three of the LOEs will have been fully evaluated during their execution. These are:

1. The mapping of total PCB and 2,3,7,8-TCDD concentrations and areas vulnerable to erosion and the use of that mapping to delineate areas to be remediated.
2. The comprehensiveness of the IR design to address the identified sediment sources.
3. The degree to which IR implementation comports with the design and effectively minimizes resuspension and redistribution of sediments.

During the performance of each of these elements, adjustments will be made (consistent with the Adaptive Management Plan [see Appendix D]) to address uncertainties. Additionally, adjustments to implementation will be made in response to any unforeseen circumstances that occur in the field, and lessons learned as the construction proceeds. This will result in higher confidence in the completion of each of the steps (delineation, design, and implementation) with agency oversight and approval. Pertinent information from each of these LOEs, such as locations with significant uncertainty or challenges that required in-field adjustments (e.g., adjustment of best management practices [BMPs] to address resuspension) will be brought into the post-IR weight of evidence assessment.

The fifth and final LOE that the IR will address is that the post-IR sediment data show no evidence of potential remaining source areas (i.e., no surface samples that are above the surface RAL). The absence of such RAL exceedances would be strong evidence of IR completion. If there are surface sediments above the surface RAL, an evaluation of the IR implementation will occur, incorporating the pertinent information from the three other LOEs above to identify and explain observed concentration patterns. If the identified sources can be effectively remediated based on size, location, and bottom type and their remediation would materially reduce the RM 8.3 to RM 15 SWACs or contaminant migration and/or accelerate long-term recovery, incremental additional removal under the IR and/or an additional FS will be proposed. Otherwise, if there are no such “actionable sources,” the IR will be deemed complete by weight of evidence. A weight of evidence assessment protocol would be developed during Remedial Design to provide a basis for characterizing sediments as actionable.

2 Lines of Evidence

2.1 Mapping of Concentrations and Areas Vulnerable to Erosion

To achieve accurate mapping, a multi-stage PDI will be conducted. The first stage will consist of sampling on a fixed grid nominally spaced at 80-feet on center from RM 8.3 to above RM 15. Geostatistical interpolation of the first stage of PDI data will be conducted for the 0- to 6-inch and 6- to 18-inch layers to provide a basis for siting infill sampling locations meant to supplement the dataset in a manner that reduces the uncertainty of the delineation, which will be developed from the second geostatistical interpolation. This would be accomplished through conditional simulation. The approach to conditional simulation, considering both total PCBs and 2,3,7,8-TCDD, would be determined after analysis of the first stage PDI data. In general, 100 conditional simulation maps would be generated and remedy footprints that yield surface sediment layer concentrations that meet the PCB and 2,3,7,8-TCDD SWAC goals would be established for each map along with targeting to meet RAO 2. These maps would be used to generate a map of the likelihood of being targeted for remediation. The second phase of sampling would be conducted where the likelihood of targeting falls in the range of 40% to 60% or where sharp concentration gradients are predicted.

After incorporating the data from the second phase of the PDI sampling, analyses of the surface sediment data would be refined to better understand spatial correlation and covariance, and the analyses would be extended to the subsurface data. These analyses will support determining an appropriate interpolation method to map both surface and subsurface sediment concentrations. Nominally, the subsurface mapping would use the data from the 0.5- to 1.5-foot layer, though adjustments may be incorporated if warranted based on assessments of depth of erosion from bathymetric differences and refined modeling. The preliminary delineation of the remedial footprint will be based on applying conditional simulation to these mappings.

The final delineation of the remedial footprint will incorporate physical characteristics (i.e., geotechnical properties, side-scan sonar-based sediment type, bathymetry, and hydrodynamic conditions) to allow for consideration of elements that can impact where contamination may (or may not) exist based on the characteristics of the river. The geostatistical mappings will incorporate some of these features to honor patterns evident in the PDI data, but manual review of those results to optimize the target areas and incorporate physical information will aid in developing a robust dredging prism.

To identify areas vulnerable to erosion, a bank-to-bank bathymetric survey will be conducted during the PDI and/or following a high flow event, if such an event occurs and a survey can be safely performed, for comparison to the 2019 baseline conditions survey and earlier multibeam surveys. Using bathymetric differencing, vulnerable areas will be defined and PDI data and geostatistical mapping (which will factor in side-scan sonar data) in those areas will be used to interpolate

subsurface (0.5 to 1.5 feet) concentrations. Those concentrations would be compared to thresholds of 2 mg/kg for PCBs and a multiplier of the 2,3,7,8-TCDD RAL that achieves the required post-remedy SWAC.[3] Where the subsurface concentrations are at or above either of the thresholds, the remediation footprint would be expanded.

An evaluation of the uncertainty of the delineation will be conducted to assess confidence that it accurately targets source areas.

2.2 Interim Remedy Design

The design will include the delineation overviewed in Section 2.1 as well as careful consideration of dredge slope stability, cut thickness, material handling, offsets from physical structures and infrastructure, and other operational constraints to minimize concerns with undisturbed and generated residuals near structures and on potentially unstable slopes.

The design will incorporate elements to control the impact of resuspension. These may include physical structures, optimizing equipment selection so that it is most appropriate for the sediment types and conditions experienced in the Upper 9 Miles, and operational controls, such as dredging during certain flow regimes and/or controlling the production rate during high flow periods to minimize the amount of sediment released into the water column from dredging operations. These elements can be incorporated into the design to meet performance standards developed during the remedial design and minimize the impacts dredging will have on the river.

A value engineering step[4] will be conducted with experienced design and construction personnel that were not directly involved with development of the design. This is most efficiently timed between the intermediate and final designs so that critical refinements can be made before contractor procurement. This step will involve engaging engineers not involved with the IR design that have experience designing and implementing large contaminated sediment remediation programs. These outside engineers will review the design and provide feedback and considerations for improving the design based on their experience. This will aid in developing an optimized and robust design.

2.3 Interim Remedy Construction

A key to IR success is the selection of a qualified and experienced contractor(s). The procurement process will include a thorough vetting of contractors to gauge their understanding of the project, experience/capabilities with similar sites, and ability to adaptively manage construction. A rigorous

[3] The subsurface RAL multiplier for total PCBs and 2,3,7,8-TCDD is set at 2.0 for the IR FS, but is subject to adjustment to between 1.0 and 2.0 after review of the PDI data.

[4] This value engineering step is specific to an outside "peer review" of the engineering design before final design (usually around the 60 percent design). It is not meant to preclude the application of general value engineering practices throughout the design process.

decision management unit (DMU) certification process will be established to evaluate the various elements of implementation (dredging, backfill or cap placement). Specifically, this process, which will occur at the DMU scale (1-2 acres) and involve review and sign off by U.S. Environmental Protection Agency (USEPA) oversight personnel, will include:

- A documentation of the dredging and capping that occurred for each DMU, including information on how the remedy implementation proceeded in the DMU.
- An evaluation of compliance of post-dredging elevations to target elevations.
- Review of bathymetry and other inspections or data (such as carbon content and grainsize) to ensure successful cap placement.
- A review of as-built maps to confirm the appropriate implementation of the design and final river-bottom condition (e.g., final offsets, cap type, etc.). for each DMU.
- Documentation of decisions and regulatory approvals, including in-field decisions that may have deviated from the design due to unforeseen circumstances and required in-field adaptations.

Solids and contaminant release during implementation will be subject to standards against which performance will be assessed, and operational adjustments will be made to meet such standards. The performance monitoring[5] for resuspension control will aid with adapting BMPs to minimize the impact of resuspension, and this part of the performance monitoring program will be weighted in the IR completion framework appropriately given the uncertainty in directly relating releases to IR completion. It is expected that the impact of disturbed residuals will be short-lived. However, information regarding areas where significant resuspension (and associated redeposition) may have occurred can be used to inform decision making based on the pattern of contamination that resulted in not declaring remedy success (e.g., broad-scale low level contamination due to resuspension) and evaluated as part of the IR Construction LOE discussed in the Section 3.

2.4 RAO Attainment

2.4.1 Post-IR Confirmation Sediment Sampling Program

Post-IR confirmation surface sediment 2,3,7,8-TCDD and total PCB concentrations will be measured according to a suitable, probability-based sampling approach that may be spatially stratified, with a sufficient number of samples to provide a statistically unbiased estimate of the post-IR SWACs for 2,3,7,8-TCDD and total PCBs and their respective 95% confidence intervals around the sample average. The post-IR sediment sampling program is anticipated to include not less than 400 and no

[5] Portions of the performance monitoring program will be incorporated into the DMU certification process and weighted as part of the remedial action implementation LOE. These include bathymetric surveys to assess dredging cut lines and cap placement and slopes, cap inspections, and cap amendment content. Other monitoring to establish whether the design was implemented, as expected, may be added. However, these would be focused on establishing the as-built condition to compare to design requirements.

more than 800 sampling locations at which three closely spaced samples will be collected and composited. The dataset may be supplemented with a second round of sampling if judged necessary to reduce the uncertainty of the SWAC derived from the data. The sampling scheme will take account of the IR design and the PDI data on which it is based. The data will be used for the statistical assessment of RAO attainment and, if that assessment does not demonstrate RAO attainment, to assess whether sources remain. If remaining sources exist, these data will be used in a weight of evidence assessment of whether these sources warrant possible remediation.

2.4.2 Use of the Post-IR Confirmation Sediment Data for RAO Attainment

Attainment of RAO 1 will be assessed by comparing the 95% upper confidence limits (UCLs) of the post-IR SWACs to limiting values that are a factor Y above the SWAC goals of 0.46 mg/kg or parts per million (ppm) for total PCBs and 85 ng/kg or parts per trillion (ppt) for 2,3,7,8-TCDD. The factor Y (which could differ for total PCBs and 2,3,7,8-TCDD) establishes a reasonable degree of equivalence in consideration of the uncertainty inherent in SWACs calculated from sample data and the possibility that SWACs exceeding the RAO 1 SWAC goals could result from post-IR sampling data even though the true means are at or below the SWAC goals.

If the 95% UCLs were to be less than or equal to Y times the SWAC goal of 0.46 ppm for total PCBs and less than or equal to Y times the SWAC goal of 85 ppt for 2,3,7,8-TCDD, the IR will be considered to have met the SWAC goals with an appropriate degree of statistical confidence and the IR would be concluded to be successful and construction is complete.

The Y values will be established based on statistical simulations of post-IR sampling data drawn from concentration maps derived from PDI data and modified such that remediated areas are assigned a residual concentration informed by modeling of IR implementation (see Attachment 1). The Y values will be set such that the expected frequency of false negatives (i.e., concluding that the SWAC goals were not achieved when the true means for the post-IR sediment surface interval are at or below the RAO 1 SWAC goals) derived from the statistical simulations is not more than 5%. USEPA considers an error rate of 5% to be acceptable for the upper bound of a potential false negative outcome that will establish the Y value for the post-IR statistical testing. This corresponds to a 95% probability of correctly concluding that RAO 1 has been met when in fact it was. The chosen Y value and the post-IR sample size will also reflect a 10% potential false positive outcome, which is also acceptable to USEPA, where the IR would be concluded to have been successful when the true post-IR 2,3,7,8-TCDD and/or total PCB SWAC(s) is/are actually greater than Y times the RAO 1 SWAC goals. While the false negative (5%) and false positive (10%) error rates are not equal, the error rates are not statistically required to be equal. The slightly different error rates reflect reasonable and industry-typical rates of error for statistical assessments and support the application of a post-IR sampling program of an appropriate scale to derive statistically unbiased estimates of the post-IR SWACs (see Section 2.4.1). The error rates also reflect an appropriate balance between errors that would

incorrectly suggest a successful IR was not successful (i.e., false negative, which could lead to a range of unnecessary additional actions to fulfill the intent of the IR) versus errors that would be recoverable (i.e., false positive) through the Adaptive Management Process that would include rigorous evaluation of system response and system recovery following the IR and culminate with the selection, implementation, and demonstration of a final remedy to address remaining risks and attain risk-protective conditions.

2.5 Post-IR Confirmation Data Source Assessment

If RAO attainment is not achieved, the post-IR surface sediment concentrations will be evaluated for evidence of potential remaining source areas. A first step would be to identify potential remaining source areas as indicated by Post-IR concentrations exceeding the PCB or 2,3,7,8-TCDD RALs. If such areas exist, a second step would be conducted to evaluate whether additional actions should be considered. That evaluation would consider:

- The magnitude of the surface sediment concentrations greater than the RALs.
- The spatial distribution, size, and location of RAL exceedances and the extent to which contiguous sampling locations form a larger area of exceedance.
- The type of sediment in which the RAL exceedances occur; in situ sediments versus deposited residuals and in remediated versus unremediated areas.
- The bottom type that exists in the area(s) of the RAL exceedances.
- The extent to which removing additional sediment may provide an efficacious reduction in RM 8.3 to RM 15 SWACs.
- The extent to which removing additional sediment reduces contaminant migration and/or accelerates longer-term recovery in the system.
- The feasibility of removing additional sediments.

A weight of evidence assessment protocol would be developed during Remedial Design to provide a basis for characterizing sediments as actionable.

3 Implementation of the Evaluation Framework

The evaluation framework will be implemented in the multi-step process embodied in the decision tree presented in Figure 2. The first step after post-IR construction sampling and data validation are complete is to compare the 95% UCLs of the SWACs calculated from the initial post-IR dataset to the limiting values established during remedial design (Y times the SWAC goal of 0.46 ppm for total PCBs and Y times the SWAC goal of 85 ppt for 2,3,7,8-TCDD, with Y potentially being different for total PCBs and 2,3,7,8-TCDD). Finding the 95% UCLs to be at or below the limiting values will demonstrate attainment of the RAO 1 SWAC goals and constitute IR success and construction completion.

If the 95% UCLs for total PCBs or 2,3,7,8-TCDD exceed their limiting values, additional sediment sampling will be conducted to supplement the initial post-IR dataset. The scope of the additional sampling would be based on an assessment of the initial post-IR dataset. Post-IR SWACs will be recalculated and refined 95% UCLs will be estimated and compared to the limiting values. Finding the refined 95% UCLs to be at or below the limiting values will demonstrate attainment of the RAO 1 SWAC goals and constitute IR success and construction completion.

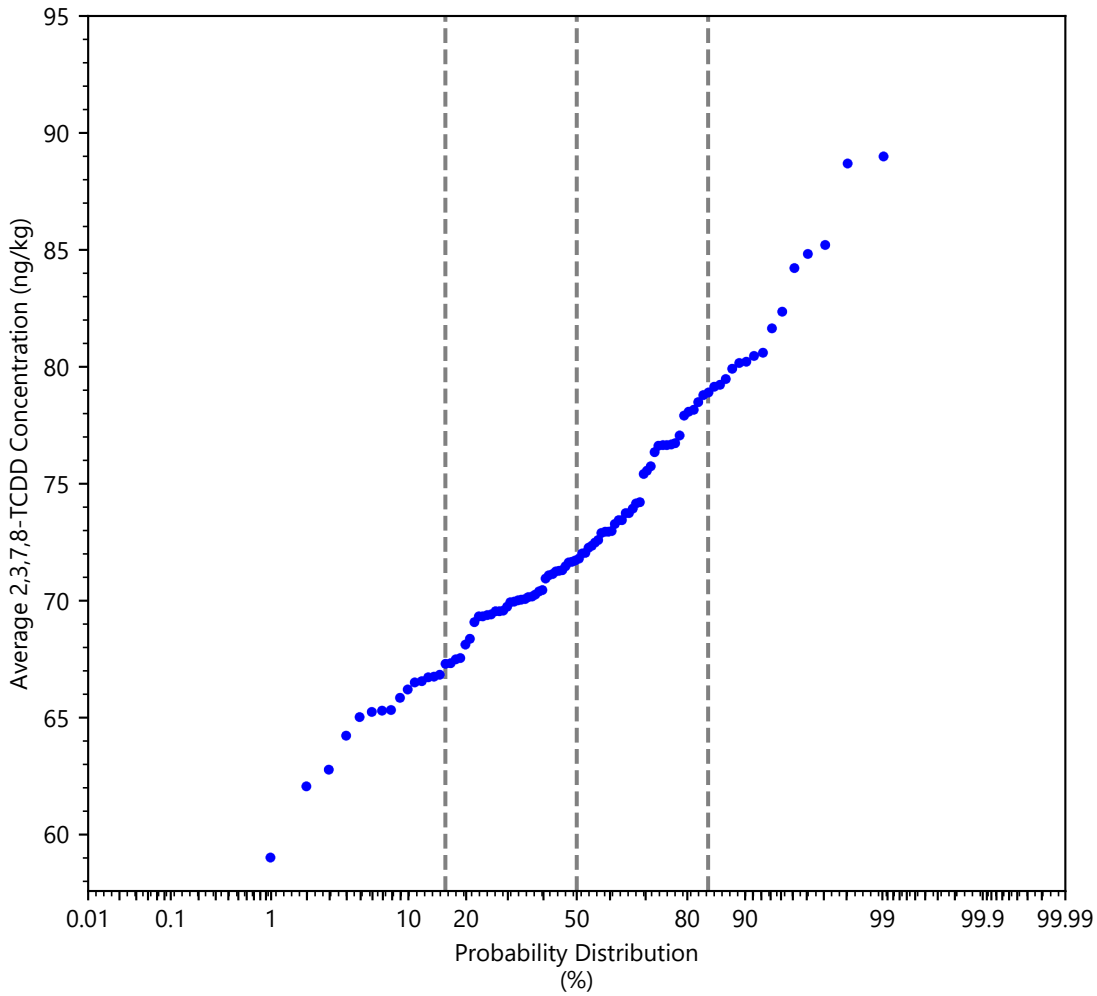
If IR success is not indicated by the statistical test, the post-IR dataset statistics will be further examined to classify the result as conclusive evidence that the RAO 1 SWAC goals were not achieved or a presumption they were not achieved. If either of the 95% lower confidence limits (LCLs) exceed the RAO1 SWAC goals, the IR will be deemed to have conclusively not met its RAO 1 objectives. If both 95% LCLs are at or below the SWAC goals, the statistical testing will be deemed indeterminate and the IR will be presumed to have not met its RAO 1 objectives.

If IR success is not indicated, the data from the two rounds of post-IR sediment sampling will be evaluated to look for possible remaining sources, as described in Section 2.5. The two rounds of post-IR sediment data and ancillary data such as sediment type mapping from side scan sonar should be sufficient for this assessment given that the sampling density will likely be multiple samples per acre.[6] If no post-IR sediments above the RAL are identified, then the IR construction will be deemed complete. If sediments above the RAL are found, they will be evaluated to determine if they are actionable. This evaluation will consider the metrics annotated in Section 2.5 and will also involve considering the analysis of IR implementation that relies on pertinent information from the LOEs described in Sections 2.1, 2.2, and 2.3. If actionable remaining source areas are identified, incremental additional removal under the IR and/or a supplemental FS will be performed to evaluate potential additional remediation.

[6] The minimum considered sampling density of 400 sampling locations equates to about 1.6 locations per acre. In the scenario of twice that density, there would be more than 3 sampling locations per acre.

The absence of actionable remaining source areas will be interpreted as evidence of IR construction completion. The pertinent information from the LOEs described in Sections 2.1, 2.2, and 2.3 will be used to identify and explain observed sediment concentration patterns during an overall evaluation of IR implementation. The findings during this evaluation of IR implementation will be used to guide performance monitoring aimed at tracking identified shortcomings of the IR and the ability of natural recovery to overcome them. The information generated from this monitoring would feed into the Adaptive Management Process aimed at ensuring acceptable progress toward risk-based goals established during remedial design and adjusted as warranted by learnings from the pre-design, implementation, and post-remedy monitoring until final remedial goals are established.

Figures



Notes: Delineation includes a total PCB RAL of 1 mg/kg, a 2,3,7,8-TCDD residual concentration of 10 ng/kg, and RA02 targeting using a subsurface RAL multiplier of 2x and the hybrid model/data erosional area definition with an erosion cutoff of 15 cm.

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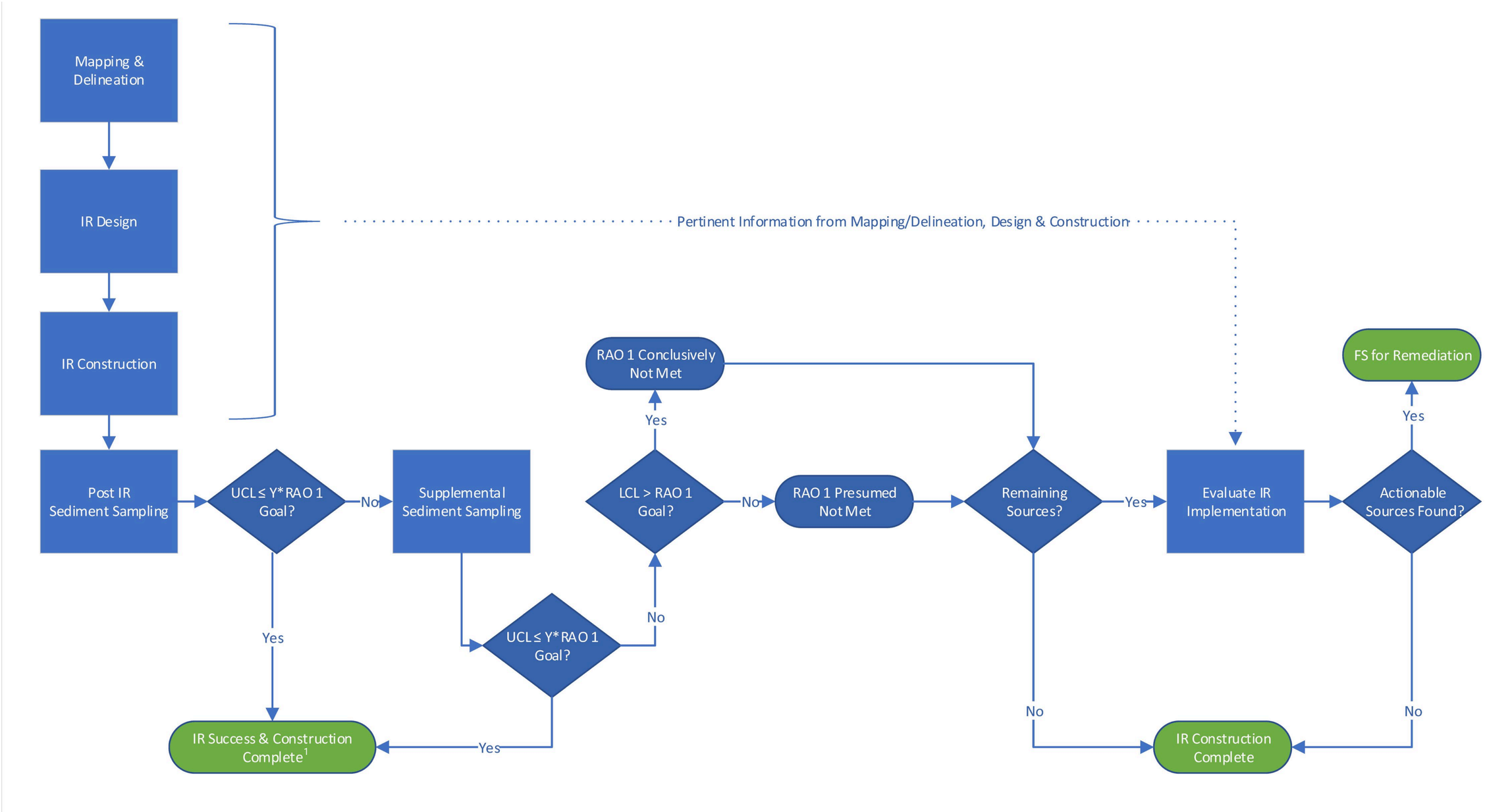
Figure 1
Distribution of Post-IR Surface 2,3,7,8-TCDD SWACs for 100 Conditional Simulations Based on a RAL of 205 ng/kg

Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area



1. In scenarios where the 95% UCL is below Y*85 ppt and the 95% LCL is above 85 ppt, data from the post-IR sediment sampling will be evaluated for possible remaining sources, as per Section 2.5.

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Figure 2
Decision Tree for IR Completion Determination
Upper 9 Mile Source Control Interim Remedy Feasibility Study
Lower Passaic River Study Area

Attachment 1
Methodology for Establishing the Y Values

1 Introduction

Pre-design data will be used to develop a design footprint. These data will also be used to establish Y values that will be applied for decision purposes following collection of the post-IR confirmation data. The Y values will be established so that the following is true:

- When the true post-IR means are equal to the RAO 1 surface area-weighted average concentration (SWAC) goals, the probability of declaring failure will be no more than 5%.
- When the true post-IR means are equal to Y times the RAO 1 SWAC goals, the probability of declaring success will be no more than 10%.

Deriving Y to meet these constraints will require development of synthetic concentration distributions that simulate each of the two scenarios (i.e., where the true post-IR means are equal to the RAO 1 SWAC goals and where the true post-IR means are equal to Y times the RAO 1 SWAC goals). These scenarios are independent of the design target SWAC and are the agreed upon levels of certainty governing the post-IR confirmation process intended to demonstrate that the RAO 1 SWAC goals have been met.

2 Data Needs

- The high-density Pre-Design Investigation (PDI) dataset used to establish the Interim Remedy (IR) footprint.
- The design IR footprint.
- The estimated total polychlorinated biphenyl (PCB) and 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) residual concentrations assumed for the remedial area, which is currently assumed to be zero for total PCB and 10 ng/kg for 2,3,7,8-TCDD. These values may be adjusted based on the results of refined modeling of the IR (accounting for background influences on residual concentrations).
- 1,000 maps of concentrations generated through Conditional Simulation.
- The number of samples collected in the post-IR sediment sampling program (anticipated to be not less than 400 individual sampling locations).

3 Steps

1. Assuming 400 sampling locations and compositing of 3 samples closely spaced at each location, for each of the 1,000 conditional simulation maps, conduct stratified random sampling of the unremediated and remediated areas (as defined by the design footprint that is established to meet the design target SWAC). The stratified random sampling will be performed using synthetic concentration distributions such that the RM 8.3 to RM 15 SWACs meet the RAO 1 SWAC goals.

2. Compute the 95% upper confidence limits (UCLs) of total PCB and2,3,7,8-TCDD surface-weighted average concentrations (SWACs) for each simulation
3. Determine tentative Y values for total PCB (Y_{PCB}) and 2,3,7,8-TCDD (Y_{TCDD}) so that:
4. 95% of the 1,000 simulated UCLs are less than Y times the RAO 1 SWAC goal.
5. If Y_{TCDD} or Y_{PCB} exceed 1.5 increase N in increments of 50 locations and repeat the previous steps until both Y_{TCDD} and Y_{PCB} are 1.5 or less.
6. With Y_{TCDD} and Y_{PCB} being 1.5 or less, adjust the conditional simulation maps so that the RM 8.3 to RM 15 SWACs are Y*RAO 1 SWAC goal.
7. For each of the 1,000 conditional simulation maps, conduct stratified random sampling of the unremediated and remediated areas using N sampling locations.
8. Compute the UCLs of total PCB and 2,3,7,8-TCDD SWACs for each simulation.
9. If 90% or more of the UCLs are at or above Y*RAO 1 SWAC goal, set N at value just simulated and Y_{TCDD} and Y_{PCB} at the values just tested. Otherwise, increase N by 50 and reconduct the analysis from the beginning.
10. Once N and Y_{TCDD} and Y_{PCB} have been established, check if increasing N by 50 locations reduces Y_{TCDD} or Y_{PCB} by 0.2 or more. If so, increase N by 50 and repeat until the change in Y_{TCDD} and Y_{PCB} are less than 0.2. Set N and Y_{TCDD} and Y_{PCB} at the values derived from this check.

APPENDIX I
GREEN AND SUSTAINABLE REMEDIATION EVALUATION

Lower Passaic River Study Area
Remedial Investigation and Feasibility Study

Prepared for
Lower Passaic River Cooperating Parties Group
New Jersey

Prepared by
integral consulting inc.

September 2021

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Table I-2. Output Results

ACRONYMS AND ABBREVIATIONS

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
cy	cubic yard
FS	Feasibility Study
GSR	Green and Sustainable Remediation
IR	Interim Remedy
LPR	Lower Passaic River
NAVFAC	Navy Facilities Command (U.S. Navy, U.S. Army Corps of Engineers, and Battelle joint group)
PCB	polychlorinated biphenyl
RAL	remedial action level
SWAC	surface area-weighted average concentration

1 Introduction

This appendix presents the input assumptions, model setup, and results produced by the SiteWise™ Version 3 Tool, a modeling tool developed jointly by the U.S. Navy, U.S. Army Corps of Engineers, and Battelle (NAVFAC 2019) to calculate the environmental footprint of remedial alternatives. It was used to evaluate the active alternatives presented in the Upper 9-Mile Source Control Interim Remedy (IR) Feasibility Study (FS) at the Lower Passaic River (LPR).

A Green and Sustainable Remediation (GSR) study analyzes the environmental impacts of the work performed for a remedial activity. For the purposes of the IR FS GSR evaluation, four outputs were selected for comparison of the impacts of the alternatives: greenhouse gas emissions, total energy used, water consumption, and potential injuries. These outputs were generated based on assumptions regarding the implementation of the remedies, including number of personnel, dredging and capping operations, material transportation to and from the site, and residual handling of the waste materials. The GSR evaluation results are relative measures of environmental footprints for comparative evaluation, and not absolute measures of impacts.

The SiteWise™ Tool is a Microsoft® Excel-based model, which includes the Input Sheet, Calculation Sheets, a Summary, and a Final Summary. The Input Sheet accepts inputs from the user into 42 different sets of variables that may be part of various remedial phases. The Input Sheet and Calculation Sheets comprise up to four stages of a remedial alternative. Outputs are calculated based on activities related to material production, transportation, equipment, and residual handling. The Calculation Sheets receive inputs from the Input workbook, and show the calculations involved in the evaluation. The Summary compares the components for a single remedial alternative and identifies activities that are the cause of the greatest impact. The Final Summary compares multiple alternatives.

For the LPR IR FS, the SiteWise™ Tool modeled the environmental impacts of each of the following active alternatives:

- Alternative 2: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD surface area-weighted average concentration (SWAC) of 85 ng/kg and PCB remedial action level (RAL) of 1 mg/kg.
- Alternative 3: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 75 ng/kg and PCB RAL of 1 mg/kg.
- Alternative 4: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 65 ng/kg and PCB RAL of 1 mg/kg.

- Alternative 5: Targeted dredge and cap from RM 8.3 to RM 15 to attain a post-IR 2,3,7,8-TCDD SWAC of 125 ng/kg.

The four active alternatives were modeled using the design criteria, material volumes and footprints, and construction and operation methods specified in the IR FS. The following information is provided in this appendix:

- SiteWise™ Inputs and Assumptions (Table I-1)
- SiteWise™ Output Results (Table I-2).

2 SiteWise™ Inputs and Assumptions

The SiteWise™ Tool models the environmental impacts of each active alternative using inputs and assumptions that fall under the following five groups:

1. Dredging and Capping Design Criteria
2. Material Production
3. Transportation
4. Equipment Use
5. Residual Handling

For each of the active alternatives, a SiteWise™ Input Sheet was completed. User information and brief site information were recorded in the Site Info section as documentation. All variables were entered into Component 1 using two types of cells. In white cells, the user typed numerical values, and in yellow cells, the user selected input from a drop-down menu.

The inputs used in the model are summarized in Table I-1 for each active alternative. For the purposes of the IR FS GSR evaluation, a series of assumptions were made to develop the model inputs to the extent available in SiteWise™. The assumptions were consistent across the alternatives for a comparative analysis of model results. Construction methods such as equipment or transportation methods were the same for all active alternatives, and duration and volumes varied across alternatives, as described by the design criteria in Appendix A.

The model assumptions for all active alternatives with the largest impact on model results were personnel, the transportation and use of dredging and capping equipment, and associated material transport. Onsite and offsite personnel include watercraft operators, engineers, surveyors, oversight staff and superintendents, administration staff, and laborers. The personnel provide a basis for the estimated amount of travel to and from the work site over the period of the active alternative.

Dredged material on the barge is to be passively dewatered with a decanting pump. The dewatered dredged material is then to be stabilized by Clean Earth using a pozzolanic material, which behaves similar to cement. The SiteWise™ model does not include a representative input for pozzolanic material, so "Typical Cement" was selected to represent the stabilizing material (7.5 percent addition by weight) in the comparative evaluation. This will be mixed using a pug mill mixer operating between 50 and 75 horsepower for a mixing rate of 95 cubic yards (cy) per hour. Capping assumptions included mixing operations and the addition of granular activated carbon (GAC). The GAC input was based on a 0.5 percent addition by volume to the cap. Mixing operations use median default values in the SiteWise™ model.

A 3 cy dredge bucket for the river shoals and a 5 cy dredge bucket for the river channel were assumed for all active alternatives in the IR FS. One limitation of the application of the SiteWise™ Tool to the IR FS alternatives is that the menu options are limited to 2, 4, and 6 cy dredge buckets. To match the design assumptions, half of the dredged material volume was averaged between the 2 cy and 4 cy bucket sizes to meet the 3 cy specification for this project, and similarly between 4 cy and 6 cy bucket sizes to meet the 5 cy specification.

Transportation of personnel was assumed to be by car, and commuting distances and times were estimated for model input. Transport for the dredged sediment and capping materials was assumed to be via watercraft and railway. Watercraft used for dredging and capping operations was selected from the SiteWise™ Tool's default list. These include 1 Light Craft (small), representing the bathymetry boat, 2 Research Vessels (large), representing scows, and 1 Light Craft (medium), representing the tugboat. These were assumed for all active alternatives and varied by the hours of operating time and labor and by fuel volumes.

After the entry of all variables and parameters, the Generate Alternative sheet runs the model and updates all workbooks within the folder with the outputs.

3 SiteWise™ Outputs

The SiteWise™ Tool outputs evaluated were greenhouse gas emissions, total energy used, water consumption, and potential injuries. These outputs were selected to illustrate the different environmental impacts among the alternatives. Table I-2 summarizes the four outputs for each of the active alternatives.

These results are based on the series of assumptions made to develop the model inputs and produce outputs for a comparative analysis, and provide relative, rather than absolute, measures of environmental impact.

The primary contributors to greenhouse gas emissions and energy consumption are equipment use during remediation activities and the transportation of equipment and materials on and off the site. The SiteWise™ modeled water consumption is calculated from electrical operations as a function of water usage associated with coal-based electrical power production (AWI 2007). Potential injuries are most influenced by the duration and worker transportation via roads and flights.

4 References

AWI. 2007. The Water Costs of Electricity in Arizona. Available at: https://1dycb0os5pn1174lbuijnlec-wpengine.netdna-ssl.com/wp-content/uploads/2009/07/Water-Costs-of-Electricity-in-Arizona-Pasqualetti.pdf. [Value for electricity generation from coal was used.] Arizona Water Institute.

NAVFAC. 2019. Green and Sustainable Remediation. Naval Facilities Engineering Command, Washington Navy Yard, DC. https://www.navfac.navy.mil/navfac_worldwide/specialty_centers/exwc/products_and_services/ev/erb/gsr.html June.

Tables

Table I-1. Inputs and Assumptions

Assumptions		Alternative 2	Alternative 3	Alternative 4	Alternative 5
Baseline Information	**Duration and Cost**				
	Duration (unit time)	4.3	4.6	4.9	3.2
	Component Cost per Unit Time ($)	91,232,558	90,218,341	101,862,766	111,778,571
Material Production	**Treatment Media**				
	Weight of Media Used (lb)	1,372,140	1,462,860	1,583,820	945,000
	Media Type	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC
	Silt Curtain Materials				
	Silt Curtain Length (ft)	5,000	5,000	5,000	4,000
	Silt Curtain Depth (ft)	10	10	10	10
	Bulk Material Quantities				
	Cap Material	Sand	Sand	Sand	Sand
	Cap Volume (ft^3)	9,801,000	10,449,000	11,313,000	6,750,000
	Stabilization Material	Typical Cement	Typical Cement	Typical Cement	Typical Cement
	Stabilization Material (lb)	69,311,039	73,893,587	80,003,651	47,734,875
Transportation	**Operator Labor - Total Onsite**	30	30	30	30
	Construction Laborers	14	14	14	14
	Operating Engineers	11	11	11	11
	Scientific and Technical Services	5	5	5	5
	Operator Labor - Total Offsite	1	1	1	1
	Remote Engineer (One site-visit per season)	1	1	1	1
	Personnel Transportation - Road				
	Cars (Commute to)				
	Fuel Type	Gasoline	Gasoline	Gasoline	Gasoline
	Distance Traveled per Commute (miles)	12	12	12	12
	Number of Trips Taken	2,025	2,157	2,298	1,484
	Number of Personnel (Above)	30	30	30	30
	Cars (Commute from)				
	Fuel Type	Gasoline	Gasoline	Gasoline	Gasoline
	Distance Traveled per Commute (miles)	12	12	12	12
	Number of Trips Taken	2,025	2,157	2,298	1,484
	Number of Personnel (Above)	30	30	30	30
	Cars (Lunch)				
	Fuel Type	Gasoline	Gasoline	Gasoline	Gasoline
	Distance Traveled per Commute (miles)	3	3	3	3
	Number of Trips Taken	2,025	2,157	2,298	1,484
	Number of Personnel (Above)	15	15	15	15
	Cars (Errands)				
	Fuel Type	Gasoline	Gasoline	Gasoline	Gasoline
	Distance Traveled per Commute (miles)	12	12	12	12
	Number of Trips Taken	405	431	460	297
	Number of Personnel (Above)	1	1	1	1
	Personnel Transportation - Air				
	Distance Traveled (miles)	1,500	1,500	1,500	1,500
	Number of Travelers	1	1	1	1
	Number of Flights	9	9	10	7
	Equipment Transportation - Rail				
	Equipment Transportation (Clean Earth to Landfill)				
	Distance Traveled (miles)	86,599,071	92,733,429	100,176,429	59,111,143
	Load (tons)	7	7	7	7

Table I-1. Inputs and Assumptions

Assumptions		Alternative 2	Alternative 3	Alternative 4	Alternative 5
	Equipment Transportation - Water				
	Equipment Transportation (Site to Clean Earth)				
	Distance Traveled (miles)	967,639	1,036,178	1,119,347	660,494
	Load (tons)	7	7	7	7
	Equipment Transportation (Clean Material to Site)				
	Distance Traveled (miles)	1,026,956	1,099,697	1,187,963	700,983
	Load (tons)	7	7	7	7
	Equipment Transportation (Debris to Rail)				
	Distance Traveled (miles)	76,071	81,459	87,996	51,924
	Load (tons)	7	7	7	7
Equipment Use	**Earthwork**				
	Equipment	Excavator	Excavator	Excavator	Excavator
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Volume of Material To Be Removed (cy)	27,765	28,447	29,504	3,360
	Diesel Vehicles have Particulate Reduction Technology	No	No	No	No
	Sediment Dredging				
	Dredge Equipment (Shoals)				
	Dredge Equipment Type	Mechanical, Crawler Crane	Mechanical, Crawler Crane	Mechanical, Crawler Crane	Mechanical, Crawler Crane
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Dredge Bucket Size (cy)	3	3	3	3
	Volume of Material To Be Removed (cy)	180,000	191,000	205,000	142,000
	Dredge Equipment (Channel)				
	Dredge Equipment Type	Mechanical, Crawler Crane	Mechanical, Crawler Crane	Mechanical, Crawler Crane	Mechanical, Crawler Crane
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Dredge Bucket Size (cy)	5	5	5	5
	Volume of Material to be Removed (cy)	155,000	167,000	184,000	104,000
	Sediment Management (Staging/Drying)				
	Earthwork Equipment Type	Crawler Crane	Crawler Crane	Crawler Crane	Crawler Crane
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Volume of Material To Be Removed (cy)	363,000	387,000	419,000	250,000
	Saturated	Yes	Yes	Yes	Yes
	Sediment Dry When Work Performed	No	No	No	No
	Diesel Vehicles Have Particulate Reduction Technology	No	No	No	No
	Sediment Capping				
	Capping Method	Direct Mechanical Placement	Direct Mechanical Placement	Direct Mechanical Placement	Direct Mechanical Placement
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Volume of Capping Material To Be Placed (cy)	363,000	387,000	419,000	250,000
	Capping Equipment Size (cy)	5	5	5	5
	Watercraft Operation				
	Bathymetry				
	Vessel Size	Light Craft (small)	Light Craft (small)	Light Craft (small)	Light Craft (small)
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Number of Vessels	1	1	1	1
	Operating Time (hours)	5,401	5,024	6,129	3,956
	Diesel Vessels have Particulate Reduction Technology	No	No	No	No

Table I-1. Inputs and Assumptions

Assumptions		Alternative 2	Alternative 3	Alternative 4	Alternative 5
	Scows				
	Vessel Size	Research Vessel (large)	Research Vessel (large)	Research Vessel (large)	Research Vessel (large)
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Number of Vessels	2	2	2	2
	Operating Time (hours)	16,202	17,257	18,388	11,869
	Diesel Vessels Have Particulate Reduction Technology	No	No	No	No
	Tug Boats				
	Vessel Size	Light Craft (medium)	Light Craft (medium)	Light Craft (medium)	Light Craft (medium)
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Number of Vessels	2	2	2	2
	Operating Time (hours)	16,202	17,257	18,388	11,869
	Diesel Vessels have Particulate Reduction Technology	No	No	No	No
	Pump Operation				
	Decanting Pump	Method 3	Method 3	Method 3	Method 3
	Pump Horsepower (hp)	1	1	1	1
	Operating Units	1	1	1	1
	Operating Time (hours)	14,852	15,888	16,925	11,053
	Mixing Equipment				
	Fuel Type	Diesel	Diesel	Diesel	Diesel
	Horsepower Range (hp)	50 to 75	50 to 75	50 to 75	50 to 75
	Capping Material Volume (cy)	363,000	387,000	419,000	250,000
	Production Rate (cy/hr)	95	95	95	95
	Other Fueled Equipment				
	Natural Gas (scf)	353,883,840	378,952,320	409,368,000	241,556,160
	Diesel (gal)	84,785	90,791	98,078	57,893
	Electrical Usage (kWh)	346,511	371,057	400,840	236,524
	Operator Labor				
	Construction Laborers (hours)	226,834	241,604	257,430	166,169
	Operating Engineers (hours)	178,226	189,832	202,266	83,084
	Scientific and Technical Services (hours)	81,012	86,287	91,939	59,346
	Laboratory Analysis, Not Finalized ($)	3,000,000	3,000,000	3,000,000	3,000,000
Residual Handling	**Landfill Operations**				
	Dewatered Sediment				
	Landfill Type	Hazardous	Hazardous	Hazardous	Hazardous
	Waste Disposed (tons)	456,000	486,000	527,000	314,000
	Methane Emissions (metric tons CH_4)	0	0	0	0
	Debris				
	Landfill Type	Hazardous	Hazardous	Hazardous	Hazardous
	Waste Disposed (tons)	36,000	39,000	42,000	25,000
	Methane Emissions (metric tons CH_4)	0	0	0	0

Notes:
cy = cubic yard
gal = gallon
kWh = kilowatt-hour
scf = standard cubic foot

Table I-2. Output Results

Metric	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Greenhouse Gas Emissions (metric ton)	459,623	522,668	601,510	233,600
Total Energy Used (MMBTU)	4,449,206	5,058,001	5,817,643	2,269,530
Water Consumption (gal)	784,187	894,391	1,029,020	393,216
Potential Injuries	58	65	74	27

Notes:
gal = gallon
MMBTU = million British thermal units

Appendix J

EPA/NJDEP/CPG IR FS Meeting Minutes

This appendix includes finalized meeting minutes that were posted to the project SharePoint site.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #1
October 24, 2018

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- EPA will provide a recap of site status – RI, source areas, SWAC, etc.
- Roles and Responsibilities – Who is responsible for minutes, agendas and action items
- Recurring meeting dates and times
- Attendee list
- FS Schedule

General:

Opening remarks by Michael Sivak (R2), Rob Law (CPG), and Michael Gordon (NJDEP)

CDM Smith will be responsible for meeting minutes and action items from each meeting will be in the minutes. EPA will provide the agendas and invites for the meetings.

Recap of Site Status:

Presentation *Feasibility Study for Evaluating an Interim Remedy for Source Control – Upper 9 Miles of the Lower Passaic River* given by EPA team to provide recap of site status. Presentation will be made available to the meeting participants by EPA.

During the presentation R2 notes EPA is not promoting collection of sampling or predesign investigation data at this stage. However, data can be collected by the CPG to inform the FS under the current AOC.

FS Schedule:

Working schedule provided by CPG is reviewed. The schedule will be reviewed and discussed in more detail at the next meeting. A final schedule is needed by the end of the next meeting.

NJDEP notes they would like this interim remedy to be a final remedy in the river, that it would meet risk-based goals and be memorialized in a Final ROD. NJDEP notes after this interim remedy, they do not want additional remediation work to be needed in the upper nine miles of the LPRSA.

Proposed Agenda for Next Meeting:

- Finalize schedule
- Discuss RAOs (to be provided by EPA)
- Discuss FS Work Plan (table of contents to be provided by CPG)

Meetings:

Schedule - November 1 (Thursday), 8 (Thursday), and 13 (Tuesday), 2018 from 10 am to noon, but meeting rooms will be reserved until 1 pm to accommodate potentially longer meeting times. The

November 1 and 8 meetings will be held at the EPA R2 office in Edison, NJ and the November 13 meeting will be held at the CDM Smith office in Edison, NJ. No meeting will be held the week of Thanksgiving, therefore, the meeting on November 13 may be longer than the two hours slotted for the earlier meetings. Subsequent meetings will be held on Thursdays and will be scheduled.

Integral will coordinate with EPA on delivering meeting information file (e.g., slide deck) prior to each meeting. EPA goal is to have CPG meeting information by COB three days before the next meeting (e.g., receive information COB Monday for a Thursday meeting).

CPG representatives and NJDEP should provide EPA with the names of people attending each meeting.

Additional Items:

Bathymetry QAPP has been provided to CPG for review and Rob Law expects it returned from them in about one week. Rob indicated CPG would like to focus on the FS, then discuss sampling. Perhaps sampling meetings/discussions could be held starting after Thanksgiving.

NJDEP asks for an updated RI delivery/review schedule. EPA will coordinate with NJDEP on NJDEP's review schedule.

Action Items:

EPA to send today's site status presentation to meeting participants (by 10/26 COB)

EPA to send draft RAOs to participants for next meeting (by 10/29 COB)

CPG to provide FS Work Plan table of contents and any other information for next meeting (by 10/29 COB)

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #2
November 1, 2018

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Schedule – Comment Discussion
- Work Plan Outline/Table of Content Discussion
- RAOs Discussion

Schedule:

Comments were presented by the EPA team to the CPG by, in summary, reviewing an alternate schedule prepared by the EPA team. The alternate schedule has FS completion and ROD signature dates close to the CPG schedule. The main difference is the alternate schedule has more detail in the line items to focus completing activities (or milestones) and encouraging the project to stay on schedule. The schedule can be fluid as the project progresses, but all parties are interested in few, if any, schedule changes.

The data available now will be used in the FS and new data being collected (e.g., bathymetry and current condition sampling) will not be used in the FS.

EPA will forward the alternate schedule and schedule comments to CPG and CPG will revise and submit a draft final schedule next week.

Work Plan Outline/Table of Contents:

The CPG's draft outline/table of contents look reasonable. The work plan table of contents and schedule contain the same elements. With the schedule revisions noted above, the work plan elements should also be revised to match the schedule.

RAOs:

Draft RAOs were reviewed and edits were made live in the meeting. The RAO file with edits made (in track changes) and text highlighted for further action (i.e., yellow – changes made at Meeting #2 and language potentially to be edited more based on further discussion; and green – text deleted at Meeting #2 with the intention of the language instead going elsewhere in the FS) will be provided to the meeting participants. A few changes will be assessed by the participants; the primary issues are that the CPG does not agree post-interim remedy sampling should be performed to determine if the SWAC goals have been met and potentially trigger additional interim remedial action if the goal has not been met, and the derivation of the interim remedy footprint by first considering RAO 1 followed by RAO 2 versus first considering RAO2 followed by RAO 1.

Proposed Agenda for Next Meeting (November 8, 2018 in Edison, NJ):

- Finalize schedule
- Discuss yellow highlighted sections of the RAOs
- Discuss SWAC goals (2,3,7,8, TCDD - 65, 75, and 85 ppt and other)

Additional Items:

No items other than the agenda items were discussed at this meeting.

Action Items:

EPA to send schedule comments and alternate schedule to CPG for CPG to revise their schedule.

EPA to send edited RAO file to participants.

EPA to discuss internally suggested changes to RAOs and post-interim remedy sampling. Also, EPA to discuss changes with NJDEP.

CPG to discuss internally suggested changes to RAOs including post-interim remedy sampling.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #3
November 8, 2018

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Discuss comments on FS schedule
- Discuss RAOs (sent by EPA via email at 2pm on 11/2)
- Initiate SWAC alternative discussion (2,3,7,8, TCDD - 65, 75, and 85 ppt and other)

Schedule:

Discussed FS schedule (revision 1) provided by the CPG on November 7, 2018. NJDEP will review the revised schedule and provide comments to EPA. CPG will make edits in response to the meeting discussion and the forthcoming NJDEP comments and submit the revised schedule to EPA.

The CPG is planning to submit the FS work plan on November 12, 2018.

RAOs:

EPA stated post interim remedy sediment sampling will be required to verify the SWAC goal has been met. EPA (John Kern) provided a conceptual approach for verifying the SWAC goal. In summary, a confidence interval will be agreed on to set the acceptable statistical certainty around the SWAC goal. For example, if the acceptable relative error is agreed to be $\pm$50%, and the SWAC goal was hypothetically 80 ppt for 2,3,7,8, TCDD, the relative error interval would be 40 – 120 ppt. The post-interim remedy sediment sampling program would be designed around the accepted level of statistical certainty (e.g., 95% confidence in the calculated SWAC). The SWAC goal would be considered met if the lower confidence bound of the SWAC calculated based on post-interim remedy sediment data was within, or below, the relative error bounds. In addition to agreeing on a statistical measure of the achievement of the RAO 1 SWAC goal, a decision tree will be developed describing actions (or sequence of actions) to occur if post interim remedy sampling indicates the SWAC goal is not met. For example, an action may be to collect additional sediment samples at targeted locations to investigate concentration distributions. In response to EPA's suggested approach, the CPG agreed, and the CPG stated they had conceived of a similar approach for demonstrating compliance with SWAC goals after Meeting #2 (November 1, 2018). Meeting participants agreed a subcommittee will be set up to define the specific statistical approach and the decision tree.

CPG stated they plan to have a larger 2,3,7,8 TCDD RAL for subsurface sediment than for surface sediment. A larger RAL for subsurface sediment would allow the interim remedy to avoid dredging some subsurface sediment that may be exposed (i.e., a possible future risk) instead of surface sediment that is already exposed (i.e., a current risk). CPG believes the subsurface RAL would be larger than the surface RAL by a factor of between 1 and 2.

Edits were made to the RAOs during the meeting and the updated RAO file will be shared by EPA with the meeting participants.

Alternatives:

CPG stated they will have the following five alternatives in the interim remedy FS:

- No Further Action
- 2,3,7,8 TCDD SWAC = 65 ppt
- 2,3,7,8 TCDD SWAC = 75 ppt
- 2,3,7,8 TCDD SWAC = 85 ppt
- Alternative with footprint smaller than the 85 ppt alternative

CPG described that the last alternative would, in summary, remediate only sediments with 2,3,7,8 TCDD concentrations at or above the upper end of the source material concentration range suggested by the CPG. The CPG said, as requested by EPA, they would be able to describe the alternative in terms of a SWAC so that it is comparable to the other alternatives. Also, CPG noted the PCB SWAC goal would need to be reduced in the last alternative because it could restrict minimizing the footprint.

Additional Items:

A SharePoint site is being set up by EPA so that the EPA, NJDEP, and CPG may share files (e.g., meeting minutes and FS schedule) for planning and developing the FS.

Next FS Meeting:

The next meeting is scheduled for November 13, 2018 from 10 am to 2 pm ET in the CDM Smith office at 110 Fieldcrest, Raritan Center, Edison, NJ (6th Floor - Rooms A and B).

Proposed Agenda:

- Determine access for SharePoint site
- Set up Subcommittee participants
- Finalize schedule
- Finalize RAOs
- Initiate footprint discussion

Action Items:

EPA to send the updated RAO file to the meeting participants. The file was emailed to the participants November 9, 2018.

EPA to check if verifying interim remedy cut lines after construction (e.g., using a global positioning system) is acceptable to confirm RAO 2 has been met.

EPA, DEP, CPG to provide a list of names (and their email addresses) for those needing access to the SharePoint site. The list should be provided to EPA/CDM Smith by November 13, 2018.

EPA, DEP, CPG to set up a Subcommittee to define the interim remedy sampling statistics and the post-interim remedy sampling decision tree. The Subcommittee names should be discussed at the November 13, 2018 meeting.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #4
November 13, 2018

Location: CDM Smith in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Determine access for SharePoint site
- Set up Subcommittee participants
- Finalize schedule
- Finalize RAOs
- Initiate footprint discussion

SharePoint site:

A SharePoint site will be established by the EPA team for sharing files for the FS. Access levels for CPG and NJDEP meeting participants were identified.

- NJDEP access:
  Viewing and downloading: All meeting participants including Michael Gordon and John Wolfe
- CPG access:
  Viewing and downloading: All meeting participants
  Uploading: Rob Law and Marcia Greenblatt
- EPA access:
  Viewing, downloading and uploading: Diane Salkie

Subcommittee:

In response to a discussion held in Meeting #3 on November 8, 2018 a subcommittee was established to, in summary, establish the statistical parameters around the development and attainment of interim remedy SWAC targets. The subcommittee will set a confidence interval to identify the acceptable statistical certainty around the SWAC goal and develop a decision tree describing actions (or sequence of actions) to occur if post interim remedy sampling indicates the SWAC goal is not met. The subcommittee members are:

- EPA: Diane Salkie, John Kern, Andy Bullard, Scott Kirchner, Ed Garland, and James Wands
- NJDEP: Anne Hayton, Myla Ramirez, and John Wolfe
- CPG: Rob Law, Doug Reid-Green, John Connolly, and Bill Locke from Integral

The subcommittee will meet on conference calls and the first call is scheduled for November 26, 2018.

Schedule:

A revised schedule was submitted by the CPG with the Draft FS Work Plan Addendum on November 12, 2018. No comments were provided by the EPA or NJDEP on the schedule and EPA directed that the CPG could use this revised schedule in the FS Work Plan Addendum.

RAOs:

In response to a DEP comment, language in Footnote #2 was edited to reference that the statistical evaluation framework will be developed in the FS. Following the edit, the meeting attendees agreed the RAOs were acceptable. The edited version of the RAO file will be reviewed by EPA counsel. EPA will send a letter/memorandum to the CPG documenting the RAOs.

Interim Remedy Footprint:

The CPG presented slides providing an overview of their proposed interim remedy alternatives and the approach of delineating interim remedy footprints. The slide deck files were uploaded to the SharePoint site and are attached to these meeting minutes.

Proposed Alternatives:

- No Further Action
- 2,3,7,8 TCDD SWAC = 65 ppt, Total PCB RAL = 1 ppm
- 2,3,7,8 TCDD SWAC = 75 ppt, Total PCB RAL = 1 ppm
- 2,3,7,8 TCDD SWAC = 85 ppt, Total PCB RAL = 1 ppm
- 2,3,7,8 TCDD SWAC = 125 ppt, Total PCB = no RAL [note that this alternative is proposed for comparative/diagnostic purposes only, with the intent to yield a smaller overall footprint to facilitate comparisons with and among the other alternatives, and would not be selected]
-

The footprint discussion included a suggestion by the EPA team that for at least one of the alternatives the CPG should calculate the size of the remedial footprint to meet RAO1 and RAO2 across the 100 conditional simulation maps. This would provide uncertainty bounds on the interim remedy area and the volume of material that would need to be remediated. This uncertainty interval should be carried through the other alternatives and possibly through cost estimating to recognize a range of possible costs for each alternative. The CPG agreed they would perform this analysis to bound uncertainty in remediation area/volume estimates, and they may carry this uncertainty into the costing or use another method (method to be determined) to capture uncertainty in the cost.

The CPG proposed the subsurface RAL for 2,3,7,8 TCDD to be a factor of 2 larger than the surface RAL. In response to a NJDEP request, the CPG agreed to conduct an analysis of the impact on RAO 2 target area of using 2 times and 1 times subsurface RAL to be presented at a subsequent FS meeting.

Additional Items:

EPA is targeting to have an RI available in February 2019 that may be approved, or conditionally approved.

Next FS Meeting:

The next meeting is scheduled for November 29, 2018 from 10 am to 1 pm ET in the EPA Edison office Room-5102-20p.

Proposed Agenda:

- Accept meeting minutes
- Discuss Subcommittee progress
- Review Draft FS Work Plan comments
- Discuss footprint delineation methodology

Action Items:
EPA and NJDEP to review the CPG's Draft Work Plan Addendum submitted on November 12, 2018 and provide comments to CPG by November 27, 2018. Comments will be discussed at the next meeting.

EPA and NJDEP to assess the proposed footprint methodology. Comments will be discussed at the next meeting.

EPA to send an invite for the first subcommittee call, which will be held on November 26, 2018.

EPA to pass the final RAO file through legal and prepare a letter to the CPG documenting the RAOs.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #5
November 29, 2018

Location: US EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Accept meeting minutes
- Discuss comments on the RAO memo
- Discuss Subcommittee progress
- Review Draft FS Work Plan Addendum comments
- Discuss footprint delineation methodology

Meeting Minutes:

The emailed comments from NJDEP and CPG on the minutes from Meeting #4 (held November 13, 2018) were reviewed. In addition to the emailed comments, at the meeting the CPG noted they did not agree with the text in the minutes about using the 100 conditional simulation maps to delineate the FS footprint. A discussion ensued about the use of the 100 maps and concluded with the CPG describing they will not use the 100 maps to draw 100 footprints but will use the 100 maps (and a revised assumption about a non-zero post-interim remedy surface concentration in the remediated areas) to establish lower and upper bounds of interim remedy scale, and EPA describing they will move ahead with EPA assessing the footprint variability across the 100 maps when some level of residual contamination (e.g., releasing 3% of the mass of surface contamination during the interim remedy, and 10% of that mass being redeposited) is considered. EPA will develop a SWAC vs RAL relationship to help assess the significance of the residuals. The results will be assessed at the next meeting (Meeting #6) and used to decide on considering residuals in the FS.

CPG indicated they will assemble text and provide it to EPA for the Meeting #4 minutes to resolve the issue of not using the 100 maps for footprint delineation, and EPA will produce final minutes.

RAO Memo Comments:

Comments made by the CPG and DEP related to the November 19, 2018 RAO Memo were discussed. Comments were made on the footnotes and the discussion component of the memo. During the discussion, DEP noted their intent in making their comments was to express their desire to achieve a high degree of confidence in the measured post interim remedy SWAC. CPG's comment related to the discussion of applying RAOs 1 and 2 (and not agreeing with the implication of an order of operations in doing so) in developing the interim remedy footprint. The group agreed to move footnote 3 to the discussion section of the RAOs, as opposed to as a footnote.

CPG indicated they will provide suggested revised text to EPA, and EPA will make edits to the draft RAO memo based on DEP and CPG comments and distribute to the meeting participants for review.

Subcommittee Progress:

CPG is working on the action items from the Subcommittee meeting held on November 26, 2018. EPA verified with the CPG some details of the action items, including that the CPG will derive summary calculations supporting the statistical framework discussion assuming both the classical null and the reverse null approach. The next Subcommittee meeting (a teleconference) was tentatively scheduled for 11 am ET on December 18, 2018. CPG will send action item results to EPA by December 14, 2018 for review.

Draft FS Work Plan Addendum Comments:

DEP reviewed the work plan addendum but did not prepare their comments yet. DEP is targeting to submit their comments early next week; EPA requests DEP (and DEP agrees) to submit the comment file to the meeting participants.

EPA comments have been prepared and EPA ORC is also reviewing the work plan addendum. EPA is targeting to send the EPA comment file to the meeting participants next week. EPA summarized the understanding that the addendum is supported by the 2015 FS work plan, and that therefore the lack of detail in the addendum is generally acceptable; however, the detail that is in the work plan addendum must be consistent with other documents and conclusions. EPA pointed out two initial comments (1- identify more citations to reference data and conclusions being made and 2 - add some language in Section 2 to better identify the significance of the meetings and meeting minutes in establishing decisions and developing the FS) during the meeting. These two comments (in more detail), and others, will be in the EPA comment file.

Footprint Delineation Methodology:

The slides presented by CPG were discussed. The slides are attached to these minutes.

CPG presented a footprint delineation approach that is largely manual. EPA suggests to use nearest neighbor or natural neighbor combined with nearest neighbor interpolation instead of relying on essentially entirely manual footprint delineation. CPG does not want to abandon the ability to establish footprint boundaries according to sediment type. CPG will consider using the nearest and/or natural neighbor interpolation method.

For the FS, the 0.5 – 1.5 ft interval is proposed for evaluating erosional areas. CPG indicates that 1.5 ft of erosion is very rare. However, if sediment coring and bathymetry data show greater depths are appropriate for interim remedy design, then greater depths would be used in the design.

EPA requests rationale is needed to support using a factor of 2 greater than the surface RAL to set the RAL for subsurface sediment that may be exposed by erosion, which CPG acknowledged is currently based on professional judgment. CPG will check at other sites (e.g., Duwamish) on how subsurface sediment was handled and develop rationale for the chosen factor.

CPG is targeting the first bathymetric survey to be conducted in December. A second survey, intended to occur after a significant high flow event, will also be conducted at a later date. These two surveys will be used to assist in delineating erosional areas. Bathymetry data from the upcoming survey will not be used in the FS to identify erosional areas, because while the data may be available, they will not be supported

by a follow-on survey empirically demonstrating bathymetric differences. The CPG confirmed their intent to utilize LiDAR during the upcoming bathymetry.

Next FS Meeting:

The next meeting was scheduled for December 5, 2018 from 10 am to 1 pm ET in the EPA Edison office (small conference room – same location as the November 29, 2018 meeting), however, due to the closure of all government buildings meeting #6 will now be a conference call on 12/6/2018 at 9:00 am.

Proposed Agenda:

- Accept meeting minutes
- Discuss Subcommittee progress
- RAO Memo
- FS WP Comments
- RAO2 Discussion (tentative – Rob will tell EPA if they are ready for a discussion on this at next meeting)

Action Items:
Team to confirm December 18, 2018 at 11 am ET for the second statistical subcommittee meeting

EPA to assess the footprint variability across the 100 maps when residual contamination is considered

CPG to assemble text and provide it to EPA for the RAO Memo and Meeting #4 minutes.

EPA to make edits to the RAO Memo and Meeting #4 minutes and distribute to the meeting participants for review

DEP to send their FS WP comments next week

EPA to send their FS WP comments next week

CPG to develop rationale for the chosen RAL factor for subsurface sediment

CPG to provide statistical subcommittee meeting action item information by December 14, 2018

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #6
December 6, 2018

Location: Conference Call/GoTo Meeting

Participants:

EPA:
Diane Salkie
Michael Sivak

CDM Smith:
Andrew Bullard
Aaron Frantz
Scott Kirchner
Keegan Roberts

CPG:
John Connolly
Gary Fisher
Marcia Greenblatt
Susan Harden
Peter Israelsson
Rob Law
Bill Locke
Hank Martin
Bill Potter
Doug Reid-Green

HDR:
Ed Garland
James Wands

NJDEP:
Anthony Cinque
Anne Hayton
Myla Ramirez

USACE:
Beth Franklin

Agenda:

- Finalize meeting minutes from 11/13 and 11/29
- Discuss latest version of RAO memo

- Briefly discuss comments on WP

Prior Meeting Minutes:

The team briefly discussed the meeting minutes from the 11/29 FS Meeting #5. Not all had reviewed these minutes, and the minutes will be left open pending review by CPG and DEP.

Relative to the 11/13 FS Meeting #4, DEP asked for clarification on the difference between delineating vs calculating the area of remedial footprints. CPG clarified that calculating the area is an exercise of hilltopping while delineation implies drawing definitive boundaries, and further clarified that the latter is not necessary to determine the aerial extent of the remediation area.

EPA indicated that both sets of meeting minutes would be finalized as soon as possible.

RAO Memo:

CPG commented that their interpretation is that the information contained within the footnotes of the RAO memo would not be footnotes within the interim remedy FS, but rather contained within the narrative of the FS. EPA indicated that some of the footnote language may actually still be footnoted within the interim remedy FS. CPG asked when it would be determined which information would remain within footnotes, and EPA responded that this would occur during the FS process, as CPG prepares the text. CPG asked if language could be included in the RAO memo indicating that decisions around which information will be in RAO footnotes vs the FS narrative will be made later. CPG also suggested that footnote 7 be removed, as it is redundant, and the team agreed this would be reasonable.

DEP asked for more time with the RAO memo, as the most recent edits had only been circulated last evening. EPA clarified that the redline version of the RAO memo being shown and discussed contains edits that are responsive to CPG and DEP comments; EPA indicated specifically that footnote 3 will be moved to the discussion portion of the memo in the final version, in accordance with a prior DEP comment. DEP asked for clarification between “active remedy footprint” and “remedial footprint”, and CPG responded there is no difference and the memo can use “remedial footprint” consistently. EPA agreed that “remedial footprint” should be used consistently. DEP indicated they are in agreement with the current footnotes 1 and 2, and with footnote 3 being moved to the discussion portion of the memo.

EPA indicated a revised version of the RAO memo would be circulated to the team for concurrence.

Draft FS Work Plan Addendum Comments:

CPG indicated that they still are reviewing the EPA’s and DEP’s comments on the draft FS Work Plan Addendum, but that they were prepared to discuss certain specific comments.

EPA Comment #17: CPG was interested in understanding the EPA’s comment regarding the requested edit to Section 2 of the FS Work Plan Addendum, and EPA responded that it is very important to maintain a distinction between the interim remedy RAOs, which will need to be demonstrated through specific measurements, and broader outcomes of the interim remedy. CPG indicated their understanding of this distinction.

EPA Comment #11: CPG was interested in better understanding the rationale for deleting Sections 1.2.1 and 1.2.2 from the draft FS Work Plan Addendum. EPA explained that it largely relates to the OU2

responsiveness summary and potential inconsistencies between it and the language in the Addendum, as well as it being generally unnecessary for the information in Sections 1.2.1 and 1.2.2 to be in the Addendum. CPG asked for additional detail related to the inconsistencies, and EPA indicated they would provide more information related to specific sections of the responsiveness summary that might conflict with the information in Section 1.2.1 of the FS Work Plan Addendum. The team also agreed to discuss this comment further at the next FS meeting.

EPA Comments #27 and #28: CPG indicated the most suitable approach may be to delete the specific date-related information from Section 3.2 of the draft FS Work Plan Addendum. The team agreed this would be a reasonable approach.

DEP Comment #1a: CPG asked for assistance from EPA in responding to this comment about the BERA; DEP indicated their position is that the BERA is not complete and that caution should be exercised regarding ecological risk conclusions. EPA indicated that there still is a planned teleconference in the next few weeks between EPA and DEP to discuss the BERA.

DEP Comment #1b: DEP is concerned that there is not a sufficient feedback loop relative to CSTAG involvement, and that the CSTAG's involvement should be better summarized. CPG indicated they would appreciate help from DEP with specific language DEP would be more comfortable with.

DEP Comment #6: With respect to RM 10.9, CPG indicated that they have not articulated one way or the other whether the RM 10.9 action was a final action. CPG clarified that existing conditions do include the prior action at RM 10.9, and therefore, that is why the No Action alternative would include the work performed at RM 10.9. DEP inquired if RM 10.9 would be included in the other interim remedy FS alternatives (i.e., the potential need to address sediments at RM 10.9 in the source control interim remedy), and CPG said yes, the RM 10.9 would be considered in the derivation of remedial alternatives and footprints. HDR recommended that this issue be framed by using post-removal action data from RM 10.9 to inform interim remedy SWAC calculations. CPG indicated they would think about this comment before the next FS meeting.

DEP Comment #9: DEP indicated that the FS Work Plan Addendum should express caution in the use of the models; CPG replied that they believe the Addendum is already sufficiently qualified relative to the use of the models. CPG agreed to revise and expand this section and requested assistance with language. DEP indicated that it would be prudent to express there will not be additional data to refine the models prior to the interim remedy ROD.

Next FS Meeting:

The next meeting (FS Meeting #7) is scheduled for December 13, 2018 from 10 am to 1 pm ET in the EPA Edison office (the same conference room as FS Meetings #1 on October 24, 2018. The specific agenda for FS Meeting #7 is still TBD, but the following topics are likely to be covered:

- Discuss/accept prior meeting minutes
- Detailed discussion of comments on the FS Work Plan Addendum
- Discuss HDR calculations regarding residuals impact on SWACs
- Discuss footprint derivation based on RAO 2
- Possible discussion of engineering assumptions

Action Items:

EPA to share HDR's residuals/SWAC calculations with the team on Monday, December 10, 2018

EPA to provide a revised version of the RAO memo for CPG and DEP concurrence

CPG and DEP to provide feedback as soon as possible on the meeting minutes from FS Meeting #5 (November 29, 2018)

EPA to provide a revised version of the meeting minutes from FS Meetings #4 (November 13, 2018) for CPG and DEP concurrence

EPA to prepare and circulate meeting minutes for today's meeting (FS Meeting #6)

EPA to provide more information related to specific sections of the OU2 responsiveness summary that might conflict with the information in Section 1.2.1 of the FS Work Plan Addendum

CPG to provide information to the team on interim remedy FS engineering assumptions prior to FS Meeting #7 (December 13, 2018)

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #7
December 13, 2018

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Discuss/accept prior meeting minutes, specifically 11/13 minutes
- Detailed discussion of comments on the FS Work Plan Addendum
- Discuss HDR calculations regarding residuals impact on SWACs
- Discuss footprint derivation based on RAO 2
- Possible discussion of engineering assumptions

Prior Meeting Minutes:

No comments were received on the November 29, 2018 meeting minutes and EPA, DEP, and CPG agreed the minutes could be accepted as final. Also, no comments were received on the December 6, 2018 meeting minutes and EPA, DEP, and CPG agreed the minutes could be accepted as final.

Additional edits made by the CPG to the November 13, 2018 meeting minutes (including the most recent change – "the CPG agreed to conduct an analysis of the impact on RAO 2 target area of using 2 times and 1 times subsurface RAL to be presented at a subsequent FS meeting") were reviewed. EPA, DEP, and CPG agreed the November 13, 2018 meeting minutes could be accepted as final, including the most recent CPG edit.

A discussion was held on memorializing meeting discussions and decisions. In meeting minutes, the discussions held and decisions made will be recorded based on the particular meeting. If, during a subsequent meeting, a discussion or decision is changed, the change will be recorded in that subsequent meeting's minutes, and previous minutes will not be changed. In addition, a separate "living" document will be prepared to record decisions. This document will memorialize the accepted discussions/decisions. The EPA team will create the living document. It will be a matrix and will identify the decisions made, along with the specific meeting minutes that document the decisions.

RAO Memo:

The RAO memo was reviewed, including final suggested edits from EPA, CPG, and DEP. EPA noted the CPG's revision specifically identifying the last FS alternative as Alternative 5 (and, in general, numbering the FS alternatives in the memo) was not appropriate, and CPG agreed. EPA, DEP, and CPG agreed the RAO memo could be accepted as final after resolving to not include the numbering of FS alternatives. EPA noted that EPA's Office of Regional Counsel will still complete its review of the RAO memo.

Draft FS Work Plan Addendum Comments:

EPA comments #11 and #14 were discussed. On the EPA comment regarding section 1.2.1 of the FS Work Plan Addendum (comment #11), the EPA team will prepare a redline markup of the suggested language and share it with the CPG.

DEP comments #1b, #2a, #4, #8, #9, and #10c were discussed. Related to DEP comment #1b, DEP offered suggested language on the role of the CSTAG recommendations (end of section 1.1 in the FS Work Plan Addendum) and DEP will share this language in an email with CPG. Another DEP comment (#9) was made on the uncertainty in modeling. CPG agreed there is uncertainty in the models and they (CPG) have, in the past, questioned the use of the models in the FS. CPG agreed there should be a cautionary note in the work plan and elsewhere about the uncertainty of the models. CPG noted Section 2.8 in the FS Work Plan Addendum has cautionary language on uncertainty in models and use of them. DEP said CPG does not need to make changes, and this comment was more a statement from DEP. The other DEP comments were discussed as follows:

#2a – DEP suggests removing "discrete" to define sources in Section 1.2. CPG suggests changing "discrete" to "identifiable" and DEP agrees.

#4 – same discussion as EPA comment #14.

#8 – CPG indicated that language from the RAOs on Adaptive Management could be added to Section 2.10.

#10c – CPG indicated that language from the RAOs could be added to the document to respond to the comment.

CPG will prepare a revised work plan and provide responses to comments with the revised document.

CPG made a case of not using the numerical model in the FS. CPG was curious how the model results would be used. For example, if the SWAC target for TCDD is 85ppt and the footprint is developed for that target, but the numerical model predicts a higher SWAC, would that be an issue for EPA? CPG asked if the ways the numerical model would be used can be identified. HDR said the role of the model in the FS is to evaluate the alternatives in a relative sense, not an absolute sense, and CDM indicated there is value in a determination from the numerical model that the FS alternatives are not significantly different from each other. CPG noted that modeling is an expensive and time-consuming effort that may not be used very much in the FS. DEP (Anne Hayton) noted that she tends to agree the numerical model should not be a critical path schedule driver. HDR reminded the group of prior discussion to use the bounding conditional simulation maps for the middle TCDD SWAC alternative of 75 ppt as an indicator of the effect of uncertainty in simulated spatial patterns of erosion and deposition and using the results to extrapolate to the other alternatives, and CPG agreed this might provide useful information. CPG says they can provide an FS without numerical modeling that provides EPA what is needed. EPA and CPG will revisit the August 14, 2018 memo provided by CPG to EPA on the advantages and disadvantages of modeling in the FS. EPA will share the memo with DEP so John Wolfe can look at it also. EPA and CPG will come to an agreement at a later date on applying numerical modeling, or not, in the FS.

The Effect of Releases during Dredging

The slides on this topic were presented by HDR and are attached; HDR's analysis is based on the assumptions that 3% of contaminant mass is lost during dredging (i.e., the same value used for the lower 8.3-mile FFS), and that 10% of that mass is retained within the top 6 inches of the sediment in the RM 8.3-15 reach. CPG notes this issue is important but suggests it is more important for design than the FS. CPG proposes they will characterize uncertainty (referred in the meeting by the CPG as "doing a probabilistic model") in the FS to assess interim remedy scale and costs rather than evaluating multiple footprints. CPG does not think it is necessary to change the footprint in the FS to account for dredging releases. CPG thinks the footprint increase due to releases can be acknowledged in the FS, but the effect does not need to be included to expand the footprints in the FS. DEP does want the additional acreage included in the FS. CPG appreciates the analysis because it identifies something that does need to be considered. It may need to be a factor in setting design criteria. DEP wants to look at this information more closely and talk internally before they decide on how to handle it in the FS. DEP would get back in a week.

EPA supports discussing interim remedy releases in the FS (how and where in the process to consider releases still needs to be decided). John Kern suggests a detailed discussion of releases is critical to the FS. He thinks the FS should aim to be as close to accurate as possible, then consider variability from that position.

CDM notes that from a previous meeting, CPG would look at non-zero replacement of surface concentrations in remediated areas, which is similar to the analysis of releases performed by HDR. EPA/CPG need to resolve this item. EPA is comfortable with 3% released and 3% retained as an upper bound for this calculation, rather than 3% released and 10% retained. HDR will update the analysis with 3% and 1% retained, and the team will look at the analysis after these updates are available to come to an agreement on the evaluation of residuals in the interim remedy FS.

Setting Footprint Based on RAO2

Slides on RAO2 were presented by CPG and are attached.

CPG presented information supporting the use of a 2x subsurface factor, including the probability of erosion even during a significant storm event being lower than the probability of erosion as suggested by the 2x factor (i.e., 50%).

CPG presented information about the selection of erosional areas. EPA (Kern) is interested in identifying areas that look depositional but could erode. A concern is erosional areas are incorrectly being identified with bathymetry (erosional areas identified from bathymetry bay be under-estimated because net bathymetry changes can be less than gross erosional changes). EPA is concerned about areas that aren't targeted for remediation because they weren't identified as erosional. EPA will look at the slide deck more closely after presentation. CPG clarified that an erosional area would be any area with an observed decrease in surface elevation of 15cm or more between 2007 and 2012 or any area with an observed decrease in surface elevation of 15cm or more between any two consecutive surveys.

CPG described two alternative approaches to evaluate erosional areas in the interim remedy FS. The first would rely on the sediment transport model to determine erosional areas, and the second would rely on a hybrid assessment of observed bathymetry and the ST model. CPG clarified that the RD would

rely on bathymetry. CPG indicated that preliminary evaluation of the FS footprint, when applying RAO2 after RAO1 and a 2x subsurface factor, shows an increase of approximately 4 acres for each of the three SWAC target alternatives (65, 75, and 85 ppt for TCDD) when using the model-only method, and between 5 and 6 acres for each of the SWAC target alternatives when using the hybrid method. If applying a 1x subsurface factor, the additional acreage approximately doubles for all scenarios. The meeting participants agreed for the desktop analysis the erosional areas identified using the hybrid approach should be applied and if the numerical model is being run, the erosional areas identified by the model should be used.

EPA will distribute the RAO2 presentation.

DEP is still unsettled about the factor of 2 in the subsurface for dioxin. As part of an analysis to check on the differences between the two factors, CPG will estimate the average 2,3,7,8 TCDD concentration in the remediated subsurface if a factor of 1 is used and if a factor of 2 is used. The CPG will also characterize the concentrations in the surface layer in areas targeted for RAO2 but not RAO1.

Engineering Assumptions:

Topic not discussed due to insufficient time. Topic to be discussed at the next meeting.

Next meeting:

The next meeting (FS Meeting #8) is scheduled for December 19, 2018 from 10 am to 1 pm ET in Room 115 at the EPA Edison office. The specific agenda for FS Meeting #8 is still TBD, but the following topics are likely to be covered:

- The application of numerical modeling in the interim remedy FS
- Using a subsurface RAL factor of 1x and 2x
- Replacement value for remediated areas
- Engineering assumptions

Action Items:

EPA team to create a matrix identifying decisions made in the meetings (and linked to the meeting each decision was made).

EPA team will prepare a redline markup of the suggested language for FS Work Plan Addendum section 1.2.1 and share it with the CPG.

DEP to share suggested language on the role of the CSTAG recommendations (end of section 1.1 of the FS Work Plan Addendum) with EPA/CPG.

EPA and CPG to revisit the memo CPG wrote to EPA on the advantages and disadvantages of modeling dated August 14, 2018. EPA will share the memo with DEP so John Wolfe can look at it also. EPA and CPG will come to an agreement on applying modeling, or not, in the FS.

EPA to update the effect of recontamination analysis with 3% and 1% retained, and to revisit upstream transport issues from Lower 8.3. DEP will look at the analysis after the assessment of 3% and 1% is available. DEP to look at the effect on recontamination information more closely and talk internally before they decide on how to suggest handling it in the FS.

CPG to estimate the average 2,3,7,8 TCDD concentration in the remediated subsurface if a factor of 1 is used and if a factor of 2 is used, and characterize the concentrations in the surface layer in areas targeted for RAO2 but not RAO1.

CPG to prepare RTC table and revised version of FS Work Plan Addendum.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #8
December 19, 2018

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Prior meeting minutes
- FS Work Plan Addendum
- Effect of recontamination
- The application of numerical modeling in the interim remedy FS
- Using a subsurface RAL factor of 1x and 2x
- Replacement value for remediated areas
- Engineering assumptions

Prior Meeting Minutes:

Minutes from the December 13, 2018 meeting were reviewed. DEP requested minor language edits and EPA and CPG agreed; EPA recorded the edits in the minutes file. Also, CPG indicated they have other suggested language changes (related to the overall use of numerical modeling in the FS and the discussion of probabilistic cost modeling in the FS) and they will send the changes in a track changes file to EPA for consideration.

As discussed at the last meeting (Meeting #7), EPA will prepare a living document memorializing the decisions made at the FS meetings. The document will be revised as the meetings progress and decisions are made.

Draft FS Work Plan Addendum Comments:

The CPG responses to comments from the EPA and DEP were reviewed. CPG noted DEP's comments are more question-based than directive-based and CPG provided answers to the questions in the RTCs.

EPA showed suggested language from DEP for Section 1.1, last paragraph on CSTAG recommendations from December 19, 2018 email. CPG and EPA agreed with language, and the team agreed, in general, that CSTAG recommendations will be followed to the extent they are appropriate specifically for the LPRSA given that CSTAG does not know everything about the site.

DEP comment Section 1.3 Objectives and Scope – switch "final" with "during" and change to "…adaptive management and memorialized in the final ROD".

Section 1.2.1 – EPA prefers to take this section out of the FS WP Addendum, as they continue to have concerns about the language in this section. The CSM will be described in the FS and it does not need to be included in the FS WP Addendum. CPG agrees to drop section 1.2.1.

The responses to comments are to be finalized by the CPG. The CPG is targeting to submit the RTCs and revised FS Work Plan Addendum (redline strikeout version and clean version) on or before January 3, 2019.

Effect of recontamination:

EPA presented results of the analysis of residuals using 3% released with 1% and 3% retained for RM 8.3 to 15. Maps considered for Areas of Remediation: 37 ("base map"), 57 (recover more quickly), and 81 (recover more slowly). CPG agrees the effect of residuals should be acknowledged in the FS but not explicitly incorporated to change the footprint in the FS; CPG agrees that the effect should be incorporated in the remedial design. CPG notes their remedial contractors will be guided to control resuspension through best management practices. DEP agrees that BMPs need to be incorporated, but that BMPs should not be the only mechanism to address uncertainty. DEP wants to think more about addressing this item in the FS or later in the RD. DEP will have a response at the next meeting.

EPA, DEP and CPG had a discussion on reasonable values to consider for percentage released and percentage retained. In summary, DEP offered values from other sediment sites that were higher than the percentages suggested by EPA at the meeting, and CPG suggested the DEP literature numbers were not applicable to values being discussed specifically for the LPR at the meeting (the CPG mentioned that the percentages identified by DEP represent values after excavation, not after the remedy (capping) is completed).

EPA reiterated that the 3% release value is from the Lower 8 FFS and 3% retained was from model simulations of capture efficiency for the Lower 8. EPA noted the issue on an expanding footprint due to percent retained was more of a concern when 10% retained was considered, but with 1% and 3% retained, the issue is not as significant (i.e., generally not more than 2 additional acres of footprint area is predicted when using 3% retained, and this impact is less than the relative difference between CS maps).

CPG noted they would consider the residuals issue through a sensitivity analysis in the FS and would like the option to reconsider the percentages released and retained in the design when additional information is available.

The application of numerical modeling in the interim remedy FS:

EPA, DEP and CPG discussed the utility and uncertainty of the models and using them, or not using them, in the FS. CPG indicated that its position is still as expressed in its August 2018 memorandum on the use of numerical modeling in the FS. EPA and DEP were in favor of using the models and CPG was not in favor of using the models.

After discussion and the CPG caucusing, the CPG proposed they will use the numerical models in the FS but would like to prepare language identifying the application of the models and appropriate "guardrails" to define the manner in which the model results will be incorporated and relied on. EPA and DEP agreed that CPG should prepare this language, which will be reviewed within the team for consensus.

RAO 2 - Using a subsurface RAL factor of 1x and 2x:

CPG has completed some additional work related to RAO 2 and subsurface RALs, but is not ready to discuss this topic yet.

Replacement value for remediated areas:

EPA would like CPG to use a replacement value other than zero for TCDD concentrations in the remediated areas and CPG stated they are not in favor of using a replacement value other than zero.

After some discussion, EPA agreed CPG will do a sensitivity analysis in the FS using some range of non-zero values (e.g., 5 and 10 ppt 2,3,7,8 TCDD) in remediated areas to demonstrate the effect of the values on footprint size compared to the zero-value favored by the CPG. In response to an EPA comment, CPG agreed the sensitivity analysis will include an evaluation of the SWAC versus RAL comparison. DEP wants to think more about this replacement idea and whether it should be addressed now in the FS or later in the RD. DEP will have a response at the next meeting

Engineering assumptions:

EPA noted the assumptions are being reviewed, and nothing looked particularly alarming on a preliminary cursory review. DEP has not yet reviewed the assumptions. EPA and DEP targeting to send comments on the engineering assumptions to CPG by January 3, 2019.

Other Items:

Sharepoint – still being worked on and access for users being set.

Action Items – will be sent out to the team immediately after each FS meeting, in addition to being documented in meeting minutes

Agenda next meeting:

- RAO2
- FS Footprints
    - Advantages and disadvantages of considering algorithmic interpolation (e.g. natural neighbor approach) vs manual interpolation for footprint
    - Addressing RM 10.9 area
- Engineering assumptions
- Revisit the timeline for discussing Current Conditions Sampling program

Action Items:

- CPG to email suggested wording for December 13, 2018 meeting minutes
- EPA to work on developing the “living document” memorializing decisions
- DEP to caucus on the analysis of residuals and the non-zero replacement idea; DEP to have a response by the next meeting
- CPG to prepare ~~a~~ draft language to describe the proposed uses of the model in the FS

- EPA and DEP to provide comments to CPG on the engineering assumptions by the January 3, 2019 meeting
- CPG to send FS work plan draft final version (redline and clean version) and RTCs; CPG aiming to send by January 3, 2019
- EPA to update meeting time for January 3, 2019 meeting (1230pm – 330pm)

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #9
January 30, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Meeting minutes from 12/13/18 (FS Meeting #7) and 12/19/18 (FS Meeting #8)
- Draft FS Work Plan Addendum status
- Modeling support for the FS status
- Engineering assumptions status
- Initiate discussion of the RAO 2 proposal from CPG
- Continue residual contamination discussion
- Decision Tracking document
- Schedule subcommittee and next FS meetings

Prior Meeting Minutes:

Meeting minutes from FS Meeting #7 (12/13/18) were reviewed. The latest file containing RLSO was provided by USACE (on behalf of EPA) on 1/7/19 and responded to with one additional edit by CPG on 1/8/19. No additional comments were offered by the team, and the minutes were accepted as final.

Meeting minutes from FS Meeting #8 (12/19/18) were reviewed. The latest file was provided by USACE (on behalf of EPA) on 1/7/19 and responded to with one edit by NJDEP (via email, not via RLSO directly in the file) on 1/16/19. The suggested revision from NJDEP was reviewed, and the minutes were adjusted based on team feedback. The minutes were accepted as final.

Draft FS Work Plan Addendum Status:

EPA indicated that comments on the January 3, 2019 revised draft FS Work Plan document are under review, and will be shared with CPG as soon as possible for discussion. CPG suggested that a conditional approval may be reasonable to allow the FS to move forward while final comments from EPA are addressed.

Modeling Support for the FS Status:

EPA indicated that EPA is in the process of incorporating NJDEP comments on CPG's January 7, 2019 modeling "guardrails" memo into comments made by CDM/HDR, and a RLSO version of the document will be provided to CPG as soon as possible.

Engineering Assumptions Status:

USACE (on behalf of EPA) provided comments on CPG's draft engineering assumptions on January 8, 2019, and CPG provided responses to those comments on January 28, 2019. Keegan Roberts suggested that CPG's responses all look reasonable, but that the issue of dredging from land should be revisited when the remedial footprints have been established. EPA indicated that concurrence on the

engineering assumptions would be provided as soon as possible, with the caveat that the ability to dredge and the extent of dredging from land be revisited in the future once remedial footprints have been established.

Discussion of the RAO 2 Proposal from CPG:

NJDEP noted that they are still reviewing CPG's January 17, 2019 memo summarizing technical justification for the RAO 2 subsurface RALs (i.e., proposed to be set at 2X the surface RALs), and they are therefore not entirely ready to discuss. However, NJDEP did express that they remain concerned by the subsurface dioxin RAL being twice the surface RAL and the possible implication for remaining sources, as well as the uncertainty in identifying erosional areas.

CPG indicated that a decision on the subsurface RAL is a critical path item to allow footprint development and modeling projections to be run, and summarized the factors that support the application of 2X subsurface RALs. CPG also noted that RAO 2 implicates a small area beyond RAO 1 and that additional bathymetry will be available from the upcoming baseline survey and possibly another bathymetry event prior to design. In response to an EPA question, NJDEP acknowledged that additional bathymetry data would improve the ability to assess erosional areas, and that current conditions sampling would improve understanding in the nature and extent of chemical concentrations.

Peter Israelsson further described the proposed RAO 2 principles, including the likelihood of exposure and the assessment of erosion potential, which he indicated reveals less than 25% of the river area that was erosional between 2008 and 2010 was erosional after 2010 and suggests that a 4X subsurface RAL factor would actually be reasonable. In response to an NJDEP question, Peter acknowledged that there are areas that were erosional after 2010 that are outside of areas that were erosional between 2008 and 2010, and therefore are not captured in the current evaluation of erosional areas, but indicated that these areas are small and would not suggest the 2X subsurface RAL factor does not remain conservative. Peter clarified that, for the purpose of setting the remedial footprint based on RAO 2, any area where 6 inches or more of erosion has been identified based on the comparisons among the five multibeam bathymetric surveys would be evaluated. The analysis of erosion after 2010 in areas where erosion occurred between 2008 and 2010 was solely for evaluating the likelihood factor supporting the ratio between the RAO 2 vs RAO 1 RALs.

Bill Locke reiterated that agreement on the footprints is needed (along with agreement on engineering assumptions) to translate the footprints into model projections, with CPG needing to launch modeling simulations in February. The team briefly discussed elements of the footprint and modeling issues, including the treatment of partial grid cells, focusing on the 75ppt alternative to derive sensitivity, and the focused application of the ST model to particular simulations. Rob Law indicated that CPG would be prepared to walk through a comprehensive presentation of footprint derivation at the next FS meeting; ultimately, the team agreed that it would be beneficial to walk through the presentation at the current meeting even if additional information would be included in the presentation later.

CPG walked through their footprint derivation presentation, which focused on the use of hilltopping to reach a target SWAC and yield a specific surface RAL (i.e., RAO 1), then the application of RAO 2 with both a 2X and a 1X subsurface RAL for comparison, based on areas outside of the RAO 1 footprint classified as erosional. Prior to the presentation, the team developed a list of six key themes that inform the footprint development approach (provided in attached whiteboard capture):

- Order of operations (i.e., RAO 1 followed by RAO 2)
- Subsurface RAL (i.e., 2X or some other multiplier)
- Approach to identifying erosional areas
- Approach to delineation (i.e., manual versus interpolation using a tool such as nearest neighbor)
- Replacement value/residuals
- Treatment of RM 10.9

Through the course of the footprint presentation, the team identified where the presentation information intersected with these six themes. CPG proposed that for the IR FS, Thiessen polygons would be reasonable to perform footprint delineation, whereas the RD would use interpolation along with manual adjustments as needed for factors such as contiguous sediment type areas. CPG also included in their presentation as defaults that the RM 10.9 area (set to 200ppt TCDD) would not be addressed during the IR, and that remediated areas would be assumed to have no residual concentrations in cap material. During the presentation, CPG summarized the calculated RALs and footprint areas based on the application of RAO 1 for the various SWAC targets, as well as the incremental impact of assuming 10ppt TCDD in remediated areas (a reduction in RAL for each alternative and an increase in footprint area of between 1 and 3 acres). CPG then summarized the incremental impact of applying RAO 2 with 2X subsurface RALs (a reduction in SWAC for each alternative of between 4 and 7 ppt TCDD along with an increase in footprint area of between 5 and 6 acres) and with 1X subsurface RALs (an additional reduction in SWAC for each alternative of between 1 and 3 ppt TCDD along with an additional increase in footprint area of approximately 2 acres for each alternative). CPG presented information demonstrating minimal change to calculated SWACs and footprint areas based on characterizing erosional areas using long-term erosion rates, which harmonizes with the projection hydrograph (as opposed to bathymetry differences).

The CPG presentation appeared to contain potentially conflicting information in a comparative analysis of the RM 10.9 area when not including versus including remediation, and CPG indicated they would verify this portion of the presentation. At the conclusion of the presentation, CPG indicated they still intended to include a few additional slides and would then share the presentation with the team.

Continue Residual Contamination Discussion:

The team did not discuss residuals specifically, other than as part of the CPG presentation on footprint derivation.

Decision Tracking Document:

CDM Smith described the current decision tracking document and its contents. The team agreed the decision tracking document should be updated and reviewed later.

Schedule Subcommittee and Next FS Meetings:

The team discussed that a statistical subcommittee meeting should be scheduled in February, but then decided that resuming discussions of current condition monitoring should be a higher priority. EPA indicated that that next three FS Meetings have been scheduled (Meeting #10 for February 7, 2019; Meeting #11 for February 21, 2019; and Meeting #12 for February 28, 2019). The team also discussed that a conference call is being coordinated for lunchtime on February 13, 2019, for which a room will be reserved at the Battelle sediments conference in New Orleans.

Other Items:

Current Conditions Sampling:

The team acknowledged that further discussion must be had on the current conditions sampling. It was noted that the Lower 8.3-mile team is still on schedule to begin in-water construction in 2021. CPG indicated they will begin steps to restart this discussion, which may include incorporating Windward for support on tissue sampling. CPG also indicated that they need for EPA to make very clear that current conditions sampling can be performed under the existing AOC. No date was set for the next discussion of monitoring.

Coordination with Lower 8.3:

CPG indicated that they would like to begin synchronizing programs between the upper 9 mile IR and the lower 8.3 mile remedy. EPA suggested that CPG can speak with whomever they wish, but EPA cannot facilitate or attend such discussions.

Action Items:

<u>EPA</u>

- Ensure everyone has SharePoint access
- Send letter to CPG pertaining to sampling
- Hold internal discussion on RAO 2 proposal (likely February 4, 2019)
- Upload meeting minutes into SharePoint
- Provide modeling guardrail comments by end of the week
- Provide response to CPG RTCs on engineering assumptions by end of the week
- Set up subcommittee meeting for late February
- Assess status of response to CPG RTCs on the FSWP Addendum and provide as soon as possible

<u>CPG</u>

- Send out presentation and maps
- Begin internal sampling discussions

<u>Modeling Team</u>

- Hold a meeting/call soon
- CPG to email suggested wording for December 13, 2018 meeting minutes

Agenda for Next Meeting:

- TBD

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #10
February 7, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Meeting Minutes
- SharePoint Access
- Continue with RAO2 and residual conversation
- Status: Engineering assumptions, modeling guardrails and FS WP
- Short agenda for 2/13

Health and Safety

As a health and safety moment, Doug Reid Green presented slides on the ice flow that occurred on the Hudson River in January 2019.

Prior Meeting Minutes

CPG and NJDEP have not finished reviewing the January 30, 2018 FS Meeting Minutes. The CPG and NJDEP will provide input on the minutes at, or prior to, the next FS meeting.

SharePoint Access

A SharePoint site has been established and the EPA Team and NJDEP have access to it. Two people from the CPG team do not have access. They report they have not received the invite to join. CDM Smith will communicate directly with the two people (one from AQEA and one from Integral) to resolve this issue and give them access. Bill Locke of Integral requested that the access issue be resolved by the February 13 call.

RAO2 and residual conversation (continued from previous meeting)

EPA noted that earlier this week CPG and EPA met to discuss these items. Also, EPA met with the DEP earlier in the week to discuss the items.

On February 4, 2019 the CPG emailed to EPA and NJDEP three files, consisting of a presentation outlining the footprint delineating process and two sets of maps (erosional areas defined by Model Predicted Long-term Erosion and by the Data/Model Hybrid Approach) using the CS-37 map to show the 85, 75, and 65 ppt TCDD footprints with a 1 ppm PCB RAL using a 2x subsurface RAL for both TCDD and Total PCBs. EPA has reviewed the slides. John Wolfe has not had a chance to provide input to DEP on the slides.

CPG assembled a summary of the February 4, 2019 slides and presented them at the meeting. While presenting the slides, the following discussions were held:

> EPA's viewpoint – the process used to develop the footprint will be in the Feasibility Study and in the Record of Decision. The process/methods being used to set a footprint now should be the

same process/methods that are used with the full data set in RD. If the process is set, but then data come back and they are poor, then EPA has the option to modify (e.g., with a ROD Amendment or Explanation of Significant Difference), but the modification needs to be considered at that time. The process being used now in the FS should be the same in the RD.

CPG comment– identifying a process is acceptable, but assumptions being made now may change when the PDI data are received. CPG wants to have the flexibility to change an assumption to be the realistic value/information found in the PDI. The CPG is mainly fixed on the RAO2 multiplier. They see a process now that could identify it as 2x (or another value), but when the PDI data are available, if the same process is used, a different multiplier may end up being better.

CPG supports using a 0 ppt TCDD residual concentration and EPA is in favor of 10 ppt. CPG notes in the Hudson River, the unremediated areas were reduced in concentrations and the theory is that some clean cap sediment was transported to the unremediated areas.

CPG wants to come to an agreement on the approach to defining the footprint in the FS, so that they can launch the modeling exercise this month (February 2019) and meet the current FS schedule.

After the presentation and discussion, the EPA team caucused, the DEP team caucused, and the CPG team caucused. Also, the EPA team met with the DEP team, then the meeting resumed.

EPA proposed that the CPG adhere to the following principles in developing remediation footprints for the IR. This proposal is focused on three primary components of the IR footprint development approach:

- Order of application of RAO 1 and RAO 2
    - RAO 1 would be applied first, by hill-topping based on a total PCB RAL of 1ppm and to achieve the SWAC target for 2,3,7,8-TCDD, sequentially followed by the application of RAO 2 to target areas
- Establishment of subsurface RALs
    - For the IR FS, the subsurface RALs would be established at a factor of two higher than the surface RALs (i.e., the total PCB surface RAL of 1ppm, and the 2,3,7,8-TCDD RAL derived through the exercise of hill-topping to achieve the target 2,3,7,8-TCDD SWAC for any SWAC alternative). EPA believes that the establishment of subsurface RALs should be supported by a rule that specifies that the subsurface RALs may be <u>no more than two times</u> the surface RALs. The IR FS would also evaluate, by way of a sensitivity assessment, the application of subsurface RALs set at some multiplier of the surface RALs that is less than two (e.g., a factor of 1.2) while preserving the sequential application of RAO 1 followed by RAO 2
- Representation of residuals
    - For the IR FS, the alternatives would utilize a replacement value of 10ppt 2,37,8-TCDD at the surface of remediated (i.e., dredged and capped) areas to simulate the impact of residuals.

EPA will provide a more detailed summary of the proposal and submit it to the DEP for consideration.

CPG responded they will assume 10 ppt in the FS, but values may be engineered to be lower and, in the RD, the value may be different. EPA acknowledged the residual number may be lower than 10 ppt TCDD in the RD.

The CPG reported they will use RI concentrations for the un-remediated utility corridor at RM 10.9 and an average concentration calculated from post-remediation sampling for the capped area at RM10.9 (thought to be about 175 ppt). CPG noted they are concerned about including areas in the footprint they cannot remediate. For the RM 10.9 utility corridor, specifically, they would like to check if the limitation to remediate over the water line can be reevaluated by the Utility and the CPG asked if EPA can support this discussion with the Utility. The CPG will find correspondence to share with EPA on the utility.

Status: Engineering assumptions, modeling guardrails and FS WP Addendum

Engineering assumptions - EPA sent a letter to the CPG today (February 7, 2019) approving the engineering assumptions.

The modeling guardrails memorandum – EPA is reviewing the memorandum. The draft comments from the EPA Team and DEP on the memorandum were shown on the projection screen at the meeting. EPA agrees fundamentally with the content of the memorandum but is suggesting some edits. The CPG noted the FS Metrics memorandum submitted February 6, 2019 is a companion to the modeling guardrails memo. EPA will finalize the comments on the modeling guardrails memorandum and submit the comments to the CPG.

FS WP Addendum – EPA accepted the FS WP addendum on February 5, 2019 on the condition that a few additional, minor comments on the file are addressed.

Other Items

- A CAG meeting is scheduled to be held tonight (February 7, 2019). EPA will give an update on the status of the FS and next steps. The CPG agrees the CAG can see the final versions of the FS meeting minutes.
- EPA is preparing a letter to provide direction to CPG to initiate the Current Condition Sampling Program

Agenda for February 13, 2019

- Finalize RAO 2 discussion
- Reach agreement on list of six FS items from February 7, 2019 presentation
- Determine where six item decisions will be memorialized

Action Items

EPA:

- Provide SharePoint access to AQEA and Integral
- Send Modeling guardrail memorandum comments
- Summarize EPA's thoughts on RAO 2 for NDEP's consultant
- Provide Current Condition Sampling Direction memorandum to the CPG
- Prepare Meeting Minutes for February 7, 2019 meeting

CPG and NJDEP:

- Review Meeting Minutes from January 30, 2019 FS meeting

Conference Call Summary
Lower Passaic River Study Area Interim Remedy Feasibility Study
February 13, 2019

Location: Conference Call; several participants met in-person (in the Executive Boardroom) at the Battelle Sediments Conference

Participants:

CDM Smith:
- Andrew Bullard (in-person)
- Aaron Frantz (phone)
- Scott Kirchner (phone)
- Keegan Roberts (in-person)

CPG:
- John Connolly (phone)
- Gary Fisher (phone)
- Marcia Greenblatt (in-person)
- Sue Harden (phone)
- Tal Ijaz (in-person)
- Peter Israelsson (phone)
- Rob Law (in-person)
- Bill Locke (in-person)
- Bill Potter (phone)
- Doug Reid-Green (in-person)
- Ben Starr (in-person)

EPA:
- Diane Salkie (in-person)
- Michael Sivak (in-person)

HDR:
- Ed Garland (phone)
- James Wands (in-person)

NJDEP:
- Anne Hayton (phone)
- Jay Nickerson (phone)
- Myla Ramirez (phone)

USACE:
- Beth Franklin (in-person)

OTHER:
- John Kern (Kern Statistical Services; in-person)
- John Wolfe (Limnotech; in-person)

Discussion Topic:

- Lines of evidence for constructing remediation footprints in the IR FS

Lines of Evidence for Constructing Remediation Footprints in the IR FS:

EPA described their current thinking regarding the application of RAO2, which includes the use of subsurface RALs set at 2X the surface RALs for the IR FS, the evaluation of remediation footprints when

applying subsurface RALs set at, or approximately at, 1X the surface RALs by way of a sensitivity analysis, and the overall application of a rule to utilize new data collected in the future to refine the actual subsurface multiplier, which is currently anticipated by EPA to set the multiplier as not to exceed 2X. NJDEP indicated they have concerns regarding specific lines of evidence being utilized for the application of RAO2, as discussed individually below.

Evaluation of Erosional Areas

NJDEP indicated they are not comfortable that 26 acres, as reported in the CPG's RAO 2 memorandum dated January 17, 2019, accurately represents all erosional areas between the 2008 and 2010 bathymetric surveys in the upper 9 miles. John Wolfe specifically indicated he derives approximately 71 acres as being erosional in the upper 9 mile reach between 2008 and 2010 when evaluating information in Appendix M, Attachment B of the RI Report. Of that acreage, John Wolfe indicated that his analysis of the information in Appendix M, Attachment B suggests that 39 of those 71 acres were also erosional from 2010 to 2011/2012, which is slightly more than 50%, which further suggests that a subsurface RAL factor of 2X is actually not conservative. The CPG indicated that there is a different threshold defining erosional in Appendix M, Attachment B (i.e., 0" for Appendix M, Attachment B versus 6" for other analyses of erosion in the RI). NJDEP did not think that this difference would necessarily explain the discrepancy; however, the CPG indicated they would revisit the analysis in Appendix M, Attachment B to determine if the RAO2 erosional probability analysis would require revision, and the group agreed with this approach. Ultimately, the group did agree in principle with the manner in which a probability factor should be established, by evaluating subsequent erosion in areas initially established as erosional. The CPG asked if the group could have discussion around a path forward, while leaving the determination of actual subsurface RAL multiplier for later, and EPA agreed that this would be reasonable.

Relative "Risk" of Dioxins vs. PCBs

NJDEP indicated that they believe a 2X subsurface RAL factor should only be considered for total PCBs because subsurface PCBs represent less "risk" than subsurface dioxins. NJDEP further indicated their belief that a subsurface RAL of 2X for RAO2 had always been intended for only total PCBs and not also for 2,3,7,8-TCDD, and pointed to the RAO memo footnote 4. The CPG indicated that RAO1 does capture some of the subsurface "threat" by addressing high subsurface concentrations while addressing surface sediment concentrations exceeding surface RALs. The CPG further noted that the relative addition of RAO2 areas if considered sequentially after RAO1 does not change significantly whether using subsurface dioxin RALs at a 2X or 1X multiplier. NJDEP indicated that they recognize the addition is only a few acres, but argued this would be valuable. The CPG indicated their belief that a subsurface RAL greater than a 1X multiplier is technically defensible. CDM indicated that a subsurface RAL multiplier of 1X would suggest that there is 100% probability of erosion, and that the available site data do not support this. EPA cautioned the group against evaluating the acreage of a remedial footprint as an indicator of remedy performance.

Actual Subsurface Concentrations

NJDEP indicated they are concerned with the magnitude of contaminant concentrations in the subsurface, the ability of 6" of sediment to provide suitable capping for an elevated concentration, and any elevated concentration being left unremediated in an area with the potential to erode given the uncertainty in erosional areas. CDM reminded NJDEP that the evaluation of erosion around RAO2 has two components; the first is the assessment of erosion for purposes of deriving a probability of erosion and a multiplier for the subsurface RALs, and the second, separate component, is the development of

remediation footprints, wherein any area classified as erosional based on the difference between any bathymetric survey pairs would be held subject to the application of subsurface RALs.

NJDEP ultimately indicated they do support the overall process and the construct of deriving subsurface RALs. The CPG asked if agreement had been reached to use 2X subsurface RALs in the IR FS, with 1X subsurface RALs considered through a sensitivity analysis. EPA indicated that they are in agreement with this approach; NJDEP indicated they do not agree with the starting point for subsurface RALs being 2X and would instead favor the IR FS incorporating 1X subsurface RALs while considering a higher multiplier through sensitivity analysis and also later during design. The CPG agreed that the IR FS would incorporate sequential application of RAO1 followed by RAO2, as long as the subsurface RALs are not at 1X (or approximately 1X) since simultaneous application of the RAOs is more efficient to achieve the RAOs with the subsurface RALs at, or approximately at, 1X. The CPG agreed to incorporate a 2,3,7,8-TCDD replacement value of 10ppt into the remedial footprint derivation. NJDEP reiterated that it supports sequential application of the RAOs, the use of 1X subsurface RALs as the starting point in the IR FS, and the 10ppt replacement value.

The group discussed that agreement has apparently been reached on the three other footprint considerations: that the IR FS will consider footprints based on Thiessen polygons while the design will incorporate interpolation methods; that the IR FS will assess erosional areas using bathymetry data with model simulations where bathymetry is not available (i.e., the “hybrid” approach discussed at previous meetings), while the model projections will incorporate the long-term erosion rate. ~~; and that t~~The RM 10.9 area will be excluded from the IR, incorporating average surface sediment concentrations over the RM 10.9 interim action area but entirely excluding concentrations above the access-restricted utility corridor for purposes of calculating SWACs. NJDEP did not explicitly weigh in on these final footprint considerations.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #11
February 21, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- **Meeting Minutes**
- **Future Meeting Plans & Topics**
- **Modeling Guardrails Memorandum Comments**
- **RM10.9 Concentrations**
- **100 Map Statistics with 10 ppt Residual Replacement Value**
- **FS Metrics**

Meeting Minutes

January 30, 2019 (FS Meeting #9) Minutes - CPG indicated they had reviewed the minutes and they have no comments. DEP had a minor question about RAO2 and it was resolved with discussion. All participants agreed the minutes file is acceptable as final.

February 7, 2019 (FS Meeting #10) Minutes – DEP indicated they had reviewed the minutes and they have no comments. CPG requested more time to review the minutes.

Future Meeting Plans & Topics

FS Meetings – Next meeting will be Thursday February 28, 2019 (agenda item is expected to be FS Metrics, which includes the incorporation of numerical modeling simulations into the metrics). Participants agreed to have additional FS meetings the 1st and 3rd Thursday of the month starting in March, with meetings to be set for March 7 and 21, 2019. CPG agreed to have a Technology Screening table for March 7.

Current Condition Sampling Meetings – CPG is having an internal conversation about sampling on March 6, 2019 and will be prepared to discuss Current Conditions Sampling at the March 21, 2019 FS Meeting.

Statistical Subcommittee Meetings – Next meeting set for March 12, 2019 at 10 am; this meeting is expected to be a conference call. Participants will discuss unfinished business from last meeting with the intent to finalize a framework for evaluating post-interim remedy sampling data and to begin developing a decision framework to assess interim remedy completion

SharePoint

All participants requesting access can access the site, except one, Bill Locke of Integral. Bill gets dropped when attempting to access the site. Marcia Greenblatt of Integral can access the site. Bill will use another browser, which may be the issue.

RM 10.9 Concentrations and 100 Map Statistics with 10 ppt Residual Replacement Value

CPG presented a slide deck describing their proposal for handling RM10.9 and the statistics using a 10 ppt residual replacement value. CPG will provide the slides to EPA. For the RM10.9 area, the CPG noted the utility corridor and "fingertip area" were not previously remediated but will be included in the footprint delineations and hill topping of the IR FS. However, the CPG also noted that the mapping in the RM10.9 area incorporates some nearshore areas that are upland, and these nearshore upland areas will not be included in footprints.

Following a question heard at a CAG meeting, DEP asked how will risk at access points (e.g., boat ramps) be assessed. EPA noted the project is not being designed to address exposure in this source removal interim remedy. However, as the project proceeds the risk can be assessed if a further action is needed. Also, EPA noted, during construction the dredging equipment is for the remedy, it would not be used to dredge in access areas to improve boat access.

Also, with this discussion, CPG brought up the agreements on modeling setup that came out of a call on February 4, 2018. The CPG will memorialize the decisions that were made on modeling in a memorandum and submit it to EPA and DEP.

Finalize RAO2 Discussion

EPA reviewed the status of the RAO2 discussion. EPA's latest proposal was that the CPG adhere to a sequential order of RAO application (RAO1 then RAO2), the 2x factor for the subsurface RAL, and the 10 ppt replacement value for 2,3,7,8-TCDD for purposes of the IR FS. DEP noted they preferred the original proposal of 1x for the subsurface RAL, but they are willing to use the 2x factor in the FS and use the PDI data and other information to determine an appropriate ratio between the subsurface and surface layer RALs that will be used in the RD footprint delineation.

The CPG asked if the 2x factor is a maximum. CPG wants to use the PDI to inform what the actual factor should be, whether it be 2x or something lower or possibly higher. DEP noted they are in favor of 2x being the maximum. EPA said a metric is needed to demonstrate the RAO has been met and the 2x maximum is needed. CPG asked what would be done if the data were to show something higher than 2x is reasonable after the PDI. EPA responded that this topic is something that can be revisited after the PDI, but for now, the 2x multiplier cap is set for the IR FS and ROD. EPA, DEP, and CPG agree to the maximum of a 2x subsurface RAL multiplier to be used in the IR FS and ROD. A modification to the decision document may be needed during the RD to increase the factor above 2X based on the PDI data, depending on the magnitude of the change.

Modeling Guardrails Memo Comments

CPG said the upfront certainty section was just a preamble to identify uncertainty, and they didn't expect that section to be carried into the final version. EPA team said to just remove the preamble on the uncertainty and focus on specifically how the numerical modeling will and will not be used for the IR FS. CPG will revise the file without the preamble or may incorporate the necessary guardrail information into the FS metrics; CPG will be prepared to discuss it next week.

A general discussion on modeling metrics followed. CPG noted three metrics they are thinking of:

- Average surface sediment concentration (SWAC) RM8.3 – 15

- Annual average surface water concentrations
- Flux of contaminants at RM8.3

CPG is considering timing of the metrics – right after remedy completion and trend after remedy completion. Also, water column concentrations and fluxes could be checked during remediation.

DEP said the model may understate the benefit of RAO2 and they would want this captured in the IR FS if it is true. CPG noted they are not intending to parse out an RAO2 benefit versus an RAO1 benefit and it is probably not doable with the model, but things may be written in general terms.

HDR reported that they had confirmed the calculation of area re-eroded, which is included in the CPG's January 17th memo to justify the 2X factor for subsurface RAL relative to surface RAL. (Areas that eroded between 2008 and 2010 that experienced re-erosion between 2010 and 2011, or 2012).

EPA suggested it may be better to present just annual averages because showing trends (or rate of change) may not be as clear, because there may be noise within the year. EPA does not want year to year hydrograph changes affecting the results.

EPA agreed the model should be used in a relative sense and not an absolute sense. The CPG suggested the comparison of alternatives with respect to numerical modeling simulations might better be through comparison of each alternative to MNR. EPA acknowledged the alternatives could be compared to MNR, but indicated they could still be compared against each other even if relative differences are very small.

FS Metrics

FS Metrics, including how numerical modeling simulations would be incorporated into the metrics, will be an agenda item for the February 28, 2019 meeting.

Agenda for February 28, 2019 Meeting

- Meeting Minutes
- FS Metrics (includes modeling metrics)

Action Items

- EPA to send meeting invites for the following meetings:
    - FS Meetings
        - Thursday February 28 (FS Meeting #12). Agenda: FS Metrics (includes modeling metrics).
        - Thursday March 7 (FS Meeting #13) and Thursday March 21 (FS Meeting #14). Agendas: TBD
    - Current condition sampling meeting – hold discussion during the March 21 FS meeting
    - Statistical Subcommittee meeting – March 12 at 10 am, it will be a call. Agenda: Pick up discussion from last subcommittee meeting
- HDR to continue efforts to confirm methods used to generate bathymetry change information in Attachment B to Appendix M (needed for explanation of apparent inconsistent information relative to RI Report Section 10).
- EPA to send a letter to CPG to memorialize the decisions on these six FS items:
    - Order of operations for application of RAOs – RAO1 followed by RAO2
    - Subsurface RAL for RAO2 – factor is 2x (max. cap) for IR FS with sensitivity analysis of 1x

- Identification of erosional areas – using the hybrid for desktop and model for long term erosion
- Final footprint delineation approach – using DUs for the IR FS (AQEA notes the DUs are set up so that they handle physical features and grain size boundaries)
- Residual/replacement value – 10 ppt 2,3,7,8-TCDD
- RM 10.9 treatment in IR FS

Additionally, the five agreed on alternatives (which include the diagnostic alternative of a 2,3,7,8 TCDD SWAC of 125 ppt) will be included in the letter

- CPG to submit Technology Screening table for March 7, 2019 meeting
- CPG to submit updated slide deck that was presented today on RM10.9 treatment area, RAO1 surface TCDD RAL and acreage from hill topping, and combined RAO1 and RAO2 acreage
- CPG to submit a file describing decisions that were made on model setup for the alternative evaluations
- CPG to review February 7, 2019 FS Meeting Minutes
- CPG to provide FS metrics (including modeling metrics) updated file or additional file for February 28, 2019 meeting discussion

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #12
February 28, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Past Meeting Minutes
- FS Metrics (including modeling metrics)

Meeting Minutes

The minutes files from the February 7, 2019 (FS Meeting #10); February 13, 2019 (New Orleans meeting); and February 21, 2019 (FS Meeting #11) meetings were reviewed. DEP indicated they have no requested edits for the February 7, 2019 or February 13, 2019 meeting minutes. Edits were made to these minutes by EPA in response to minor comments from the CPG, after which the participants accepted the February 7, 2019 and February 13, 2019 minutes. The CPG also requested that revisions be made to the February 21, 2019 meeting minutes, which DEP indicated they have not yet thoroughly reviewed. EPA indicated they will revise the February 21, 2019 meeting minutes in accordance with the CPG's requested edits, and then DEP will review the revised meeting minutes.

Modeling Metrics

The participants discussed *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS* and *IR FS Metrics* both dated February 27, 2019 and submitted by the CPG. EPA and DEP noted the files have not yet been reviewed because they were submitted yesterday and the files are only being discussed at today's meeting (i.e., official comments are not being presented at the meeting).

EPA indicated the interim remedy alternatives should be compared to each other, not just individually to MNR, which is the current proposal in both documents that were discussed.

The CPG noted the model simulation results will be presented as ranges and there will be overlap of the ranges, and that the differences between alternatives will be assessed within all the metrics of the analysis, not just recovery. The CPG noted they need to see the results of the models before they can determine how to interpret the overlap. The CPG noted the FS Team will see results and interpretation of the results.

DEP said the CPG should not prematurely underrate what the models may be used for now. DEP expressed a concern that the model guardrails may be structured to lead to a conclusion that there are indistinguishable differences between alternatives. The CPG noted the model is a blunt tool, but differences between alternatives should not be indistinguishable because at a minimum, there will be differences in the concentration space; however, the CPG noted that other metrics will be used. EPA expressed that the interim remedy is for source control, and therefore it should not be expected that

there would be large differences in the performance of the interim remedy alternatives. The CPG noted they are not intending to ignore results from the model if they can be used. DEP concluded if information from the model is going to be used and not dismissed, then they (DEP and the CPG) are in agreement.

The CPG noted they do not believe they should look at modeling metrics for RM 0-8.3 or RM 8.3 to Dundee Dam, which is not in accordance with a comment from EPA (on the prior version of the *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS* document) to consider these reaches. The CPG noted that the modeling work will assess flux across RM 8.3. The EPA team will check this comment on RM 0-8.3 and RM 8.3 to Dundee Dam and assess if it should be retained, or not.

As noted by the CPG, there is a specific edit to be made on the modeling projection metrics table: in the third cell of the third column, delete "rate of" so entry reads "Percent increase compared to MNR alternative".

HDR suggested providing absolute values, not just percent change, when comparing model projections for the IR alternatives to one another and to MNR. For example, the CPG should present a table of cumulative flux at a certain point for each alternative and figures presenting cumulative flux over time for each alternative. The CPG can do a comparison of percent reduction relative to MNR as proposed, but HDR is recommending cumulative flux be evaluated also, not just a percent reduction. This comment will be included in the comment set being prepared for the memorandum.

The CPG requested when the model metrics are being reviewed, the team should identify components/data needs to prepare a well-designed PDI so the collected information can be used in the model to improve the ability of the model to be more useful in design and during the adaptive management process.

DEP asked if QA procedures/methods are being used when preparing and running the model. The CPG replied yes, a lot of work has been done and is being done for validating the models.

EPA mentioned an issue on RI Report Appendix M, Attachment B – HDR cannot duplicate the results presented in this attachment and EPA is making a recommendation to resolve the issue within the RI. Assumptions were described in the attachment that the FS Team does not agree with now. Therefore, the CPG will revise the attachment with current agreed on rules/assumptions regarding treatment of bathymetry data for evaluating erosional and depositional areas, and the inconsistencies between the attachment and other portions of the RI will be clearly described in the RI Report. On a separate topic specifically for the FS, it was noted that the erosional probability factor method and results presented by the CPG for application of subsurface RALs for RAO2 were confirmed by HDR.

In response to a DEP question, the CPG noted the RI edits will have no impact on the FS process. The change will provide additional information and it will not change the overall conclusion or CSM. In addition, no parameters in the model are affected by this change in Appendix M, Attachment B. EPA will prepare a summary of the Appendix M, Attachment B issue and resolution for DEP.

The CPG noted they are rewriting RI section 10.5 in response to a comment from EPA and the CPG asked if generating confidence limits using the bootstrapping method from pre- to post-Irene conditions is acceptable. EPA indicated they will communicate with John Kern and respond to the CPG.

The CPG's due date to deliver a completely assembled version of the RI Report to EPA is March 29, 2019. The CPG will send a redline strikeout version and a clean version. Also, a revised Appendix K is being delivered by the CPG on March 4, 2019 for the EPA Team to check the appendix before it is added to the March 29, 2019 submittal.

EPA noted the estimated completion date for the RI is spring 2019. EPA will consider making a conditional approval; also, EPA indicated that they may make some edits themselves to achieve conditional approval.

EPA noted the bioaccumulation model won't be final for the RI, as it will need peer review. The RI conditional approval letter would note the status of the bioaccumulation model.

FS Metrics

The *IR FS Metrics* table prepared by the CPG was discussed.

EPA asked if the CPG is considering discussing sustainability metrics via a specific GSR tool, and the CPG responded that they have not specifically identified a tool they might use. EPA indicated that the CPG should recognize the FS will be reviewed by many, so they should incorporate green remediation components/discussion into the FS because this information is often expected. The CPG should evaluate against the nine FS criteria, recognizing that sustainability is not in and of itself an FS criterion; however, having a discussion or adding a section to discuss sustainability is important. EPA noted that the CPG could describe how sustainability can be incorporated into each FS criterion. The CPG indicated they do not expect that sustainability considerations will introduce significant differences among the IR alternatives.

DEP initiated a discussion on controlling residuals for the short term effectiveness criterion. The CPG responded the remedial design will address residual generation and the best practices to manage residual generation. A description of the capping practices and BMPs to cover quickly and control residuals would be included in a common element section of the FS.

On the implementability criterion, the EPA suggested to include synergies with the lower 8 remedial action in the FS. The CPG noted they will include the RM 10.9 utility and "fingertip" areas in the footprint, and they will also include other difficult areas (e.g. utility crossings and bridge abutments). The CPG noted they have all intention of remediating these areas. They noted they have talked with dredging companies regarding ways to remediate these challenging areas. The CPG also noted that they may ultimately decide to remediate in locations outside of RM 10.9 to avoid areas previously armored with stone.

In response to a question from the CPG, EPA/DEP preliminarily identified a list of items they may want to see as the FS is developed:

- Table of contents
- Common elements
- Cost estimate framework
- Technology screening
- Decision tree for success
- Adaptive management discussion
- ARARs

- Maps of the remedies, footprints, volumes, schedules and model setup

EPA/DEP will think more about items that they would like to see early.

Agenda for March 7, 2019 FS Meeting

- Files reviewed today (*Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS* and *IR FS Metrics)*
- Technology Screening (if available from the CPG)

Action Items

- EPA to send the edited February 21, 2019 Meeting Minutes to DEP. DEP to review the edited file
- CPG to send edited February 07, 2019 Meeting Minutes to team
- EPA to prepare, as requested by DEP, an explanation of the RI Appendix M Attachment B issues and resolution
- EPA to ask John Kern if he agrees with the CPG's proposal on revising RI Section 10. 5 to generate confidence limits using the bootstrap method from pre to post Irene conditions.
- EPA – is finishing developing the letter on the decision for the six FS items and will send letter to FS Team
- EPA and DEP to review the *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS* and *IR FS Metrics* sent by CPG on February 27, 2019
- DEP to review the *Approach to Running FS Projections* slide deck dated February 4, 2019
- EPA and DEP to review the file (*Lower Passaic River Interim Remedy Feasibility Study Summary of Projection Modeling Approach* February 28, 2019) sent today by CPG that is a summary of modeling agreements. When EPA/DEP accepts, the CPG will start the modeling activity
- CPG to send team a list of FS topics for discussion
- CPG to send team Technology Screening Memo and ARAR Memo

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #13
March 7, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda:

- Meeting minutes: CPG comments on February 7, 2019 (Meeting #10) Minutes; Approval of February 21, 2019 (Meeting #11) Minutes DEP based on in-meeting changes; Review of February 28, 2019 (Meeting #12) Minutes
- EPA and DEP comments on: *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS, Lower Passaic River Interim Remedy Feasibility Study Summary of Projection Modeling Approach* and *IR FS Metrics* that were submitted by the CPG and are dated February 27, 2019
- Technology Screening submitted by CPG March 4, 2019
- Subcommittee Meeting agenda
- Agenda for March 21, 2019 Meeting

Meeting Minutes

February 7, 2019 (Meeting #10) Minutes - CPG made edits to this file on February 28, 2019 (Meeting #12). EPA accepted the revised file. DEP is reviewing the edits and will provide a review response to EPA.

February 13, 2019 Meeting Minutes (teleconference with some participants at Battelle Sediments Conference) – all agreed the minutes were approved at the February 28, 2019 Meeting (Meeting #12).

February 21, 2019 (Meeting #11) Minutes – The CPG provided edits to this file at the February 28, 2019 Meeting (Meeting #12). EPA accepted the revised file. DEP reviewed the revised file and indicated their acceptance at this March 7, 2019 Meeting (Meeting #13). EPA will post the approved minutes to SharePoint.

February 28, 2019 (Meeting #12) Minutes – CPG asked for one change: Under the FS Metrics section on Page 3 at the end of the first line add "prepared by the CPG". EPA accepted the revised file. DEP will review this minutes file and provide a review response to EPA.

Modeling Metrics

Consistent with a discussion started at the February 28, 2019 (Meeting #12) meeting, EPA commented to the CPG to assess the SWAC at RM0-8.3 and RM8.3-15 and flux at RM0, RM8.3 and RM15, but they do not need to assess the SWAC above RM15. Each metric should be assessed over time. EPA provided this comment because of the need for EPA to be in a position to explain the potential impact the alternatives being evaluated may have on the river, including in the RM0-8.3 reach. EPA recognizes the effect on the lower 8 from the interim remedy at RM8.3-15 is likely small compared to the impact of the work in RM0-8.3. After some discussion, CPG agreed to assess the SWAC and flux as commented by the EPA.

EPA repeated a comment from the meeting last week that alternatives should be compared to each other, not just the MNR alternative. CPG said they will assess the comment when it is officially received from EPA. EPA noted they understood the uncertainty in the model and the comparisons need to be assessed appropriately when the model results are available. CPG noted the model is a blunt tool and they think putting too much emphasis on the model results is a very slippery slope because some people will interpret the results as being more-meaningful than they should be. EPA noted that those who are more knowledgeable about the models will not over-interpret the results. EPA will be considering model results relative to each other and recognizes the model results should not be interpreted in absolute terms. EPA will continue to carry the message of using the model results correctly as has been discussed at the meetings. In addition, it was noted that the model will only be one of a number of lines of evidence used to support FS remedial decisions. EPA will provide formal written comments on the Model Metrics and FS Metrics Memos.

The meeting transitioned to discussing the DEP preliminary comments on various FS deliverables from their March 5, 2019 email.

Generated Residuals – DEP requested a statement be added to the CPG's memo summarizing the FS projection modeling approach regarding minimizing/managing residuals. CPG accepted the comment from DEP, however, the CPG does have an issue with the phrase "complete sequestration". The CPG will offer language that they will use best management practices to minimize residual contamination.

Footnote 5 (page 3 of the memo summarizing the FS projection modeling approach) - CPG offered this clarification to DEP: To represent remediation in the CFT model, a factor is used and that reduction factor is applied down to 5 ft because the model is not explicitly representing the effects of capping. DEP understood the explanation/clarification.

On the 7th bullet of the CPG's revised modeling "guardrails" memo and information contained in the FS Metrics document, regarding overlapping model results – DEP explained the comment. CPG reiterated their concern that model results should be used and interpreted only to the extent the model uncertainty allows the evaluation. DEP's point was just because there is overlap, doesn't mean there aren't meaningful differences. CPG noted if the graph made by DEP was reversed (i.e., the MNR is better than the action), CPG would still recognize the action is better than MNR. CPG pointed out that the uncertainty results will not be like the example graph shown by DEP, because the uncertainty ranges will only be developed for the 75 ppt case and then scaled to the other target SWAC cases. After this discussion, DEP recognized the idea being provided in the comment may not be achievable, so the comment will be revised.

CPG asked for the official comments from DEP soon because the direction may change how the CPG looks at uncertainty.

EPA noted this is an interim remedy and the model output is only one criterion that will be evaluated in this source control remedy. Also, the CPG noted there may be only 1 or 2 ppt differences between model results and the other FS criteria would far outweigh these small differences.

The participants acknowledged comments on the Modeling Metrics could change how CPG will set up the model. EPA does have some comments/suggestions that will affect the model, and they will be provided today. If DEP has comments that would change the setup of the model, then these should be sent to CPG as soon as possible. DEP will caucus early next week, then provide final comments on the files.

The meeting transitioned into discussing DEP preliminary comments from their March 6, 2019 email on the *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS, Lower Passaic River Interim Remedy Feasibility Study Summary of Projection Modeling Approach.*

Preliminary comment- Table on Page 2

a. CPG response: The projection period is 10 years post remedy
b. DEP suggests using relative changes rather then percent changes. CPG agrees.

Other preliminary comments from the March 6, 2019 email were discussed. Official comments will be provided by the DEP.

FS Metrics

Preliminary comments from the DEP March 6, 2019 email were discussed. After the discussion, CPG requested DEP to provide input by Tuesday March 12, 2019.

Preliminary EPA comments were discussed. On the *Reduction of toxicity, mobility or volume through treatment* criterion - CPG said sediment treatment to prepare for shipment will be included in the FS discussion. CPG noted the treatment technologies retained in the technology screening table. On the *Ability to progress toward overall protection* criterion, the participants acknowledged risk is not a criterion in the interim remedy, but the removal of contaminants will reduce risk, like the action at RM10.9. Also, in a response to an EPA preliminary comment, the CPG will discuss mass reduction in the FS when evaluating metrics for the alternatives.

DEP added a preliminary comment on percent reductions. DEP noted they are not clear how a range of percentages will be developed, they didn't think a range would be developed if the error bars are scaled in the same way. A discussion was held on the percent reductions approach. CPG noted comparisons are being made between alternatives not between the maps of an alternative.

EPA and DEP will prepare an official set of comments and the comments will be submitted to the CPG.

Technology Screening

This file was received from the CPG on March 4, 2019. EPA and DEP will review the file. Comments on the screening will be provided at a date to be determined.

Subcommittee Meeting Agenda (Meeting March 12, 2019)

- Continue discussing statistical framework for demonstrating post-IR SWAC target attainment
  - Briefly recap Dec 19, 2018 discussion
  - Review EPA slides
  - Discuss required consensus points and decisions
- Begin discussing post-IR decision and follow-on action framework
- CPG alternate approach to demonstrating compliance with RAOs

Agenda for March 21, 2019 Meeting

- Current conditions sampling (Windward will be part of this discussion)
- Future FS discussions/decisions and a schedule to accommodate

- Next FS Meeting (hold open April 4, 2019 but this meeting date is not yet on schedule)

Action Items

- EPA and DEP to memorialize comments on:
    - *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS,*
    - *Lower Passaic River Interim Remedy Feasibility Study Summary of Projection Modeling Approach* and
    - *IR FS Metrics*

The goal is to send the comments to the group by close of business on Monday (3/11/19) and discuss any issues on the subcommittee call on Tuesday (3/12/19). If there is a major issue(s), that requires more discussion, a meeting will be held on 3/14/19 in Edison.

- EPA and DEP to review the Technology Screening Memo
- CPG to send out the ARAR memo
- EPA to finalize the FS decision memo and send to the team
- DEP to review meeting minutes from 2/28 and the updated meeting minutes from 2/7

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #14
March 21, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Meeting Minutes
- Modeling memoranda and FS Metrics memorandum
- Future FS discussions/decisions and a schedule to accommodate
- Technologies Screening Memo discussions
- Current conditions sampling
- Next FS Meeting

Meeting Minutes

February 7, 2019 (Meeting #10) Minutes – DEP reviewed the latest edits (edits made at the February 28, 2019 Meeting [Meeting #12]) and accepted the minutes. The minutes had been accepted by EPA at the March 7, 2019 Meeting (Meeting #13).

February 28, 2019 (Meeting #12) Minutes – DEP reviewed the latest edit (edit as requested by the CPG at the March 7, 2019 Meeting [Meeting #13]) and accepted the minutes. The minutes had been accepted by EPA at the March 7, 2019 Meeting (Meeting #13).

March 7, 2019 (Meeting #13) Minutes – The CPG noted they had no comments. DEP indicated they are still reviewing the minutes.

Modeling Memoranda and FS Metrics Memorandum

EPA submitted comments to the CPG and the CPG accepted the suggested edits for the following memoranda:

- *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS*
- *Lower Passaic River Interim Remedy Feasibility Study Summary of Projection Modeling Approach*
- *IR FS Metrics*

In addition to accepting the edits, the CPG suggested alternate language for one item in the *Regarding the Use and Limitations of Model Projections* memorandum and the suggested edit was shared in the meeting. EPA and DEP accepted the suggested language. Therefore, this memorandum was accepted as final and will be posted to SharePoint by EPA.

The CPG noted they are still making revisions and additions to the *Summary of Projection Modeling Approach* memorandum and will send the updated version. Questions from DEP were resolved with the CPG earlier in the week on a telephone call. Also, information was received from EPA yesterday (March

20, 2019) on cap properties and EPA is checking on the boundary condition file to be used by the CPG. EPA will inform the CPG today if the file is the correct file. When the file is confirmed to be correct, the modeling projections can be started by the CPG.

The CPG had no issues with EPA/DEP suggested edits on the *IR FS Metrics* memorandum and they will send the final file (with edits accepted) to EPA.

In response to a DEP question on how water quality standards are being handled for the IR, EPA noted, and DEP acknowledged, the IR will focus on sediment and water quality will be deferred to the final remedy. EPA does not believe a waiver is needed for water quality requirements for the IR, but EPA will verify this understanding. Also, EPA noted the next FS Meeting (to be held April 4, 2019) will be used to discuss the process for the interim and final remedy using CERCLA language. EPA will distribute a summary of the CERCLA process for the site before the next meeting.

In response to a DEP question on evaluating long-term effectiveness and the distribution of post-IR concentrations relative to pre-IR concentrations, the CPG noted that a visual depiction of before and after concentrations could be shown. Another method may be to show the changes in charts (e.g., cumulative distribution plots). The CPG noted these are simple ideas/methods to show how the IR may change the concentrations and distribution of those concentrations.

EPA noted they are holding a meeting with public officials on April 23, 2019 in the Lyndhurst Senior Center to present the status of the site activity, the proposed approach to the IR, and benefits of the IR for adjacent municipalities. EPA will invite DEP to say a few words at the meeting. The community advisory group (CAG) is also invited. EPA is preparing slides for this meeting and will share the slide deck with DEP.

Future FS Discussions/Decisions and Schedule to Accommodate

An ARARs table is being developed by the CPG and it will be submitted within the next two weeks.

Technology Screening Table Discussion

EPA discussed preliminary comments on the technologies screening table with the CPG. No major comments were identified, and the CPG was receptive of the preliminary comments. A final comment set on the technology screening table will be provided to EPA by CDM next week, and EPA will send the final comments to the CPG.

DEP noted they oppose the use of a confined disposal facility (CDF) or a confined aquatic disposal (CAD) cell as a disposal technology. The CPG clarified that the CDF process option was not retained in the technology screening in the lower 8.3 mile FFS, but that the CAD process option was retained. Neither a CDF nor a CAD were selected in the ROD remedy for the lower 8.3 mile . The CPG will add language to the table to note DEP's opposition and that the CDF process option was not retained in the lower 8.3 mile FFS. Also, in response to a DEP comment on implementability for the *in-situ* treatment technology, the CPG will remove the note suggesting the technology had demonstrated success in the LPR. This comment will be included in the final comment set to be sent to EPA next week and then sent by EPA to the CPG.

The technology screening table will be revised by the CPG in response to the comments from EPA, and the revised table will be in the draft FS. If further discussion is needed on the table, then the CPG would submit it for review prior to submitting it in the draft FS.

Current Conditions Sampling

The CPG presented an overview of their proposed current conditions sampling program. One element of the proposed sampling program is a bathymetry survey (including multibeam and single beam bathymetry, LiDAR, and side-scan sonar) in year 1, and this survey is ongoing and nearly complete. The CPG noted that another bathymetry survey would be completed in year 2 or year 3 following a high flow event (greater than 10,000 cfs over the Dundee Dam), or later if these conditions are not experienced in year 2 or year 3. Such an event would correspond to roughly a 5-year storm event.

The CPG noted their current conditions sampling program is intended to be based on an adaptive approach, wherein changes could be made to the approach to and/or timing of subsequent sampling events based on prior sampling event results. The CPG also noted that overall timing of the current conditions sampling relative to work in the lower 8 would be considered, ensuring that adequate sampling data are collected in the time between now and the start of in-river work for the lower 8.3 remedial action.

A preliminary discussion on biota, water and sediment sampling was held.

On biota sampling, the CPG noted they are proposing two years of tissue sampling (years 1 and 3) rather than the three years recommended by CSTAG. The CPG noted they are confident they will collect sufficient specimens in terms of both sample size and targeted species in year 1, then in year 3 they will get a current snapshot before the IR. The CPG noted if they don't collect sufficient samples in year 1, additional supplemental sampling could occur in year 2. The CPG intends to conduct tissue sampling in the fall. EPA and DEP noted that CSTAG recommended three years of tissue data and the two years, as proposed by the CPG, would need to be further evaluated.

The CPG proposed to perform sediment coring in conjunction with the benthic invertebrate community sampling in year 2, and to collect fine-scaled core intervals during this sampling to support the food web model. DEP asked for the CPG to identify how these data will be used in the food web model. The CPG noted they will address this at the next meeting, and today is just a high-level overview of the proposed sampling program.

The CPG could implement physical surface water data collections early this summer. The CPG noted the logistics of getting contractors and equipment and refining methods are variables in the schedule and that they are not currently aware of results from surface water monitoring underway in the lower 8.3 miles which would inform the data collection for the upper 9 mile program. Also, the CPG noted that surface water sampling equipment would be removed from the river for the winter to avoid damage to the equipment.

EPA noted their food web modeler will present the food web model (its development, calibration, and status) to DEP on April 3, 2019, then DEP will participate in the subsequent food web model meetings.

The CPG agreed to provide additional details on its proposed baseline sampling work during the April 4 FS Meeting.

Subcommittee Meeting

It was noted that meeting minutes have not been prepared for the prior subcommittee calls/meetings. At future subcommittee meetings, EPA will assign someone to take meeting notes. Slide decks used at the past meetings will be retained to record the meeting discussions.

At the next subcommittee meeting, the members need to discuss the decision tree. The CPG noted they need to know from EPA the criteria to be used to determine remedy complete. EPA noted they will have this discussion internally and with DEP, and provide information to the CPG prior to the next subcommittee meeting.

Proposed Agenda for Next FS Meeting (April 4, 2019)

- Technology Screening Table
- ARARs Table
- FS Items for Submittal and Schedule
- The CERCLA Process for the Lower Passaic River 17 Mile Study Area
- Current Conditions Sampling

Action Items

- DEP to review the March 7, 2019 (Meeting #13) Minutes
- EPA and DEP to consider the current conditions sampling proposal suggested by CPG today and be prepared to provide input/discussion at the April 4, 2019 meeting
- EPA to send comments on the FS Technology Screening table, including DEP comment
- EPA to prepare a description summarizing the CERCLA process for the IR and final remedy prior to the April 4, 2019 meeting
- EPA to send feedback to CPG on remedy complete considerations for the decision tree; this will be sent after EPA talks with DEP
- CPG to submit the edited (based on EPA/DEP comment) three documents
    - *Regarding the Use and Limitations of Model Projections in Evaluating and Comparing Remedial Alternatives in the IR FS,*
    - *Lower Passaic River Interim Remedy Feasibility Study Summary of Projection Modeling Approach* and
    - *IR FS Metrics*
- CPG to submit ARARs table

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #15
April 4, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Meeting minutes
- Technology Screening Table
- ARARs Table
- FS Items for Submittal and Schedule
- The CERCLA Process for the Lower Passaic River 17 Mile Study Area
- Current Conditions Sampling

Meeting Minutes

March 7, 2019 (Meeting #13) Minutes – The DEP reviewed the file and has no comments. During the March 21, 2019 Meeting (Meeting #14) the CPG indicated they have no comments. The minutes were accepted.

March 21, 2019 (Meeting #14) Minutes – The DEP offered one edit to the file and the CPG also made edits to the file. This CPG edited file was provided to the EPA, and the EPA added the DEP comment. The EPA will share the edited file for the EPA team, the DEP and the CPG to review the file.

Technology Screening Table

The CPG will make changes to the Technology Screening Table in response to the EPA and DEP comments dated April 2, 2019. The revised table will be submitted by the CPG to the EPA for review.

ARARs table

The EPA and the DEP are reviewing the ARARs table submitted by the CPG on March 27, 2019. In the meeting the CPG noted they referred to the ARARs in the Lower 8.3 Mile ROD (and also shown in the RD Work Plan) to prepare the ARARs table for the Upper 9 Mile FS.

FS Items for Submittal and Schedule

The Draft FS Table of Contents submitted by the CPG on March 26, 2019 was shown by the EPA at the meeting. No comments were provided on the table of contents. The EPA, DEP, and CPG agreed the next FS Meetings would be on May 9, 2019 (Meeting #16) and June 6, 2019 (Meeting #17) and telephone calls, if necessary, could be scheduled between the meetings. EPA will send invites for the two meetings. The Basis of Cost Estimate and a description of an alternative would be discussed at the May 9, 2019 meeting. The outline of the CSM would be discussed at the June 6, 2019 meeting.

The Interim Remedy Process

The *EPA Anticipated LPRSA Process for Both Interim and Final Actions* (Interim Remedy Process) prepared by EPA and dated March 29, 2019 was discussed. The CPG noted they began reviewing the file and developed some questions and comments, but they need to continue their review. The NJDEP also noted they will review the file and provide comments. The CPG asked for the Interim Remedy Process to be placed on the next meeting agenda.

Next Subcommittee Meeting

The CPG reported they are working on a decision tree outlining the actions to take in response to the surface weighted average concentrations (SWACs) of 2,3,7,8-TCDD and Total PCB measured after the interim remedy. The decision tree would be discussed at the next subcommittee meeting. The next meeting (Meeting #4) was scheduled for May 2, 2019 and it will be a conference call. The EPA will send an invite.

Current Conditions Sampling

The CPG shared a slide deck presenting their proposal for current conditions biota sampling. A detailed discussion was held about the proposed sampling and the significant notes are included here.

The CPG noted the program is organized around the primary DQO, to evaluate trends over time. The secondary DQO was to refine and validate the food web model.

The RM14.7 referred to in the slide deck (e.g. page 4) is RM15 of the FS convention.

The CPG noted they did not propose catfish and bass for sampling because they had difficulty catching these species during the remedial investigation. EPA said these species should be included because they are in the food web model (thus, they can help with the secondary DQO).

The CPG proposed composite samples, but EPA said they prefer individual fish analyses (for species large enough to meet analytical tissue mass requirements) because this provides more flexibility in evaluation.

The CPG noted their intent is to detect trends over time using a graphical analysis. The EPA noted they prefer statistical analyses to assess trends.

CPG proposed three fish per composite sample because they are confident that they can catch three fish per year to repeat this sample size for each subsequent sampling event.

The CPG proposed sampling in four reaches above RM 8.3: Four composites per species for each of the lower two reaches and two composites per species for each of the upper two reaches for a total of 12 composites for each species.

The EPA, DEP and CPG noted they need to come to an agreement on the biota metric (or metrics) for measuring the success of the interim remedy. This item will continue to be vetted with the three parties.

EPA noted the proposal does not include benthic invertebrate tissue analysis and the BERA shows risks to the benthic invertebrates from their tissue concentrations, and to birds that eat these organisms.

The CPG said they don't want to use the Bligh-Dyer method for lipids because the method involves chloroform and labs don't want to run it.

The EPA suggested that aging the fish samples (via otolith analysis) is important for determining growth rates for use in the food web model. The CPG said they believe they can sacrifice some fish to age the samples and they will consider this recommendation. The CPG noted they do collect length and weight of the fish, which are two measurements that may be used to estimate age.

EPA noted chemical analyses in addition to dioxin/furan and PCB is needed to account for the adaptive management monitoring. CPG noted they will look at the risk drivers in the HHRA and BERA and consider those analytes.

After a meeting break, a slide deck was shared by the CPG presenting their proposed surface water sampling program.

The CPG noted the discussion revolves around 2,3,7,8-TCDD and PCB but acknowledged the earlier comment about analyzing other risk drivers.

CPG noted the goal to deploy Acoustic Doppler Current Profilers (ADCPs) in June and have them in through November (6 months of data).

The CPG described background sampling is mid-channel, not a transect, and sampling will be done from a bridge for ease of access (like during times when flow is elevated). The CPG noted if data for RM14 show results like RM16.1, they may stop sampling at RM14.

CPG also noted they want to test a larger sampling volume instead of 1L of water. They will use a peristaltic pump to get 8L, and the greater volume may result in achieving lower detection limits. CPG plans to propose a pilot study to check on this method.

The CPG noted they have been in contact with their team consultant that will conduct most of the sampling tasks. The CPG noted the schedule in the slide deck indicates the earliest time they would be in field is June 1, but the pilot test could delay initiating the chemistry sampling.

The CPG is considering options to collect high volumes for compositing suspended solids because that is where the remedy effect is expected to be seen first.

The EPA offered these preliminary thoughts on surface water sampling:

> The CPG should recognize that Moffatt and Nichol's analysis of the location of the estuarine turbidity maximum (ETM) as a function of flow was based on depth averaged salinity.
>
> When selecting locations for cross channel transect measurements, the size of the refined model grid cells should be considered.
>
> The number of sampling events needs to be evaluated more closely. The sampling frequency will continue to be discussed.

EPA noted the sampling proposed to be conducted by the CPG in Year 3 (2021) should be moved to Year 2 (2020). The lower 8 remedy is scheduled to start in July 2021 and, thus, sampling time in 2021 would be lost assuming sampling in the upper 9 miles should be complete before the lower 8 remedy starts. The NJDEP also noted they had a concern with the PDI sediment sampling schedule.

EPA noted the conversation on current condition sampling needs to continue and a call will be setup by the EPA.

Action Items

- EPA and DEP to review the edits made by CPG on the March 21, 2019 (Meeting #14) Meeting Minutes

- EPA to send invites for next FS Meetings May 9, 2019 (Meeting #16) and June 6, 2019 (Meeting #17)

- EPA to send an invite for the next subcommittee call scheduled for May 2, 2019

- CPG and DEP to review *EPA Anticipated LPRSA Process for Both Interim and Final Actions* dated March 29, 2019

- CPG to provide the proposed lipid method if they do not use the Bligh-Dyer method

- EPA and DEP to review the CPG's biota and surface water sampling proposal offered today (April 4, 2019)

- EPA to coordinate with the FS team (EPA, DEP and CPG) to schedule a call/meeting to continue today's (April 4, 2019) sampling discussion, possibly April 11th afternoon

- CPG to send out amended version of the Technology Screening table

- EPA and DEP to review ARARs table

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #16
May 9, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Meeting minutes and next FS meeting
- EPA LPRSA process document
- Common engineering elements
- Basis of cost estimate

Meeting Minutes

EPA, DEP, and CPG agreed that prior edits to the March 21, 2019 (FS Meeting #14) meeting minutes were acceptable (these minutes were edited as noted in the April 4, 2019 [FS Meeting #15] meeting minutes), and the minutes were accepted as final.

DEP and CPG reported they had no comments on the April 4, 2019 (FS Meeting #15) meeting minutes, and the minutes were accepted as final.

DEP and CPG are reviewing the minutes from the meetings held on April 11, 2019 (Current Conditions Sampling Meeting #3), April 17, 2019 (Current Conditions Sampling Meeting #4), and April 18, 2019 (Current Conditions Sampling Meeting #5).

Process Document

DEP and CPG comments on EPA's overall process document (dated March 29, 2019) were discussed. CPG's comments were provided by way of a separate process document. CPG reported that their version of the process document follows the general organization of EPA's version but emphasizes the importance of adaptive management.

CPG noted their belief that preliminary remedial goals (PRGs) should not be developed prior to the interim remedy (IR) record of decision (ROD), and the best time to develop PRGs would be after the IR is complete. CPG indicated that a primary tool in the development of PRGs will be the food web model (FWM), that this model will not be completed until after the IR ROD, and additional calibration of the model will likely be performed following the IR. CPG further indicated that after the IR, it will be necessary to evaluate the relationship between sediment and tissue concentrations, and noted an overall concern with uncertainty in sensitive parameters needed for the development of PRGs that may change after the IR. EPA agreed that the FWM is key to back calculating PRGs from fish tissue to sediment, and noted that the current conditions sampling in addition to sampling performed after the IR will give a better look at the relationship between sediment and tissue concentrations. DEP indicated they do not see a technical basis for delaying the development of PRGs until after the IR. DEP stated that PRGs could be developed now with the RI, BERA, and HHRA, but they do not expect the PRGs to be available before design. CPG indicated that if they do develop the PRGs prior to the IR they will need some flexibility to adjust as monitoring proceeds. EPA acknowledged that PRGs may change after more

site information is generated, but that significant changes are not likely and any changes to the PRGs that are defensible would be permitted. EPA indicated that this process can be laid out in the adaptive management plan, and be part of the decision tree. CPG expressed that they do not want the IR success to be measured relative to PRGs. CPG also expressed that there is uncertainty in how background may affect the recovery of sediment and tissue and the development of PRGs; specifically, background may control the development of PRGs, not so much for dioxin, but possibly for a subset of the chemicals.

CPG noted their position that whether to collect post-IR sediment samples and when and how those data would be used is still an open question. EPA indicated that they have discussed the concepts of post-IR confirmation sampling with CSTAG, and that they would set up a call between EPA, DEP, CPG, and CSTAG to discuss post-IR confirmation sampling.

CPG noted that work is needed to align the administrative pieces of the process properly. Specifically, CPG expressed that they are not certain the 17-mile AOC needs to go on indefinitely; rather, they think activities can at some point be rolled into the remedial design AOC, and they do not want multiple CPG groups working on more than one AOC at one time. DEP indicated their understanding that the 17-mile AOC would prevail until the final ROD. While indicating that nobody present is an attorney, EPA clarified that administrative enforcement may be under different AOCs, so long as there is an active enforcement mechanism at any given time. EPA indicated they do not know yet what instrument will be in place at what time. The current 17-mile AOC contains tasks that will not be done by the completion of the IR ROD (e.g., setting final cleanup goals), and has otherwise been modified to include developing the IR FS (i.e., the October 2018 direction letter from EPA). CPG is required to close out the open tasks of the existing AOC. EPA can leave open the existing order and open other AOCs (e.g., the remedial design AOC with separate tasks), or open a remedial design AOC (with the existing AOC tasks added, then close the existing AOC). However, EPA will decide on the best route, and EPA attorneys will need to work this out.

DEP noted they provided other questions/comments and asked if they would be responded to. EPA noted that a merged process document should be prepared, and CPG offered to create this document. To respond to DEP's questions/comments, CPG indicated they will update the process document with the input provided. EPA asked if DEP wanted to discuss anything in particular. EPA noted the team has been having subcommittee calls/discussions and EPA believes the discussion will be moving more to adaptive management.

FS Common Elements and Basis of Cost Estimate

EPA and DEP comments on the CPG's FS common elements and basis of cost submittals were discussed. DEP indicated that they did not receive the basis of cost document, and EPA noted that they had forwarded it to DEP earlier in the morning. EPA requested that CPG send files directly to the entire team.

DEP asked to clarify that the fourth alternative alluded to in the common elements document is the alternative that will be included in the FS for comparison only. CPG confirmed this is the case.

CPG indicated that they would sample for waste characterization purposes during the dredge material management process, and not through in-situ sampling prior to remediation. EPA asked CPG to provide rationale for the assumption that all dredged sediments would go to a subtitle C disposal facility. CPG indicated that this assumption is probably consistent with the lower 8 assumption. CPG will take it under advisement to review the assumption and will look at how it affects costs. CPG specifically noted that they will include a sensitivity analysis around waste disposal costs in the FS.

CPG confirmed that there will be permitting and it will be a lump sum line item in the FS costing.

DEP asked if "dredge to clean" should be part of the common elements. CPG responded that it will not be specifically integrated into any alternative and will not be costed, but it will be described in the FS (likely in the common elements description).

DEP asked if habitat would be restored or replaced, and noted they would like the word "approximately" to be removed from the statement "remedial design will include management…to ***approximately*** restore the habitat and avoid net loss of habitat". CPG noted that habitat could be restored through the inclusion of appropriate substrate material in the cap that is placed at the site. However, CPG clarified that any cap material would need to meet performance requirements in addition to habitat substrate considerations.

DEP requested that CPG integrate the ultimate decision on post-IR confirmatory sampling into the common elements of the FS, and CPG agreed. CPG also indicated that the FS will contain an appendix documenting lessons learned from the RM 10.9 removal action.

On cost sharing for the sediment processing facility to be constructed for the lower 8 mile remedial action, CPG proposed an assumption that the processing facility would be available and used to support the upper 9 mile IR. CPG indicated that it is a goal of the upper 9 mile IR to synchronize with the lower 8 action. CPG indicated that their understanding is the lower 8 processing facility would have sufficient capacity; however, CPG also noted that they are not certain this capacity would be available to the upper 9 IR and that they have not talked with the lower 8 group about this cost sharing. CPG noted that the Clean Earth facility at the Hackensack River may be an option to handle the volume of sediment from the IR, and that they will consider the cost implications of the lower 8 processing facility potentially being unavailable. EPA expressed that they do not believe the IR FS should essentially be the first time that synchronization between the upper 9 and lower 8 is summarized. EPA noted they will check with their attorneys to understand how this should be handled in the FS and ROD.

The team also briefly discussed the ARARs document that was previously circulated. CPG indicated that they received ARARs comments from EPA on May 6, 2019 and they have no issues with the comments. DEP is still reviewing the ARARs table.

EPA and DEP confirmed they would submit written comments on CPG's common elements, ARARs, and basis of costs documents by May 17, 2019.

Current Conditions Sampling

CPG indicated that the physical surface water sampling QAPP will be submitted to EPA and DEP next week. CPG also noted that the low volume chemical surface water sampling QAPP will be arriving in June. CPG did not have a submittal date for the high volume chemical surface water sampling QAPP.

CPG noted that the delivery of sampling QAPPs for biota sampling is not certain, and they are waiting to see John Kern's sample size computations and also want to understand the specific study questions about DQO #1 from EPA's perspective. John Kern indicated he would be submitting the power analysis calculations today. EPA and DEP indicated they will look at the biota sampling memo received from CPG on May 7, 2019.

The team agreed to schedule another call on the biota sampling, for either May 28 or May 30, 2019. CPG will get back to EPA on which day works best.

Next FS Meeting

The next FS meeting, FS Meeting #17, was set for June 6, 2019 from 1 pm – 4 pm Eastern at EPA Region 2 in Edison, New Jersey.

Also, the team agreed to have another call on FS-related items (ARARs, common elements, and basis of costs) and overall adaptive management. The call will be on May 22, 2019. EPA will send an invite for 10 am – 12 noon Eastern.

The team discussed a possible CSTAG meeting on May 14, 2019 to discuss post-IR confirmation sampling.

Action Items

EPA to check with ORC on the CPG making assumptions for cost in the Interim Remedy FS for using lower 8-mile RA facilities

EPA to schedule a call with EPA, CSTAG, DEP and CPG for May 14, 2019 to discuss post IR sediment sampling

EPA to schedule a call with EPA, DEP and CPG for May 22, 2019 to discuss FS Items (ARARs, Common Elements and Basis of Costs) and Adaptive Management

EPA to schedule a call with EPA, DEP and CPG for May 28 or 30, 2019 to discuss the Current Conditions Biota Sampling memo

EPA and DEP to review the *Passaic Current Conditions Biota Sampling* memo dated May 6, 2019. EPA to provide response to CPG on questions for EPA's proposed DQO #1.

EPA and DEP to review the CPG's *Common Engineering Elements* dated May 6, 2019 and *Basis of Cost Estimate* dated May 7, 2019. Target delivery date of comments to CPG is May 17, 2019

DEP to review the CPG's ARARs Table dated March 27, 2019. Target delivery date of comments to CPG is May 17, 2019

DEP and CPG to review the April 11, 2019; April 17, 2019 and April 18, 2019 meeting minutes

CPG to update the *EPA Anticipated LPRSA Process for Both Interim and Final Actions* based on discussion at the May 9, 2019 meeting

Meeting Minutes
Diamond Alkali OU4 Interim Remedy Feasibility Study
Meeting #17
May 22, 2019

Location: Web conference/phone call

Participants:

U.S. Environmental Protection Agency (EPA) Team:
Diane Salkie
Beth Franklin
Abby Broadstone
Andrew Bullard
Ed Garland
John Kern
Scott Kirchner
Keegan Roberts
James Wands

New Jersey Department of Environmental Protection (NJDEP) Team:
Anne Hayton
Jay Nickerson
Myla Ramirez
John Wolfe

Cooperating Parties Group (CPG) Team:
Betsy Day
Gary Fisher
Marcia Greenblatt
Sue Harden
Tal Ijaz
Peter Israelsson
Rob Law
Bill Locke
Doug Reid-Green

Agenda

- Further discuss the process document (CPG's amended version)
- Initiate adaptive management discussion
- Discuss EPA and NJDEP comments on ARARs, common engineering elements, and basis of costs

Discussion

EPA asked if there are any major issues outstanding with the ARARs, common engineering elements, or basis of costs documents previously shared by the CPG. The team agreed there are no major outstanding issues with any of the documents, and the CPG indicated they would develop and share responses to the comments received and integrate the responses into the IR FS. The CPG asked for clarification on one NJDEP comment on the capping element of the common engineering elements. Specifically, the CPG asked what NJDEP means by future use for capped areas, and NJDEP responded that there are recreational uses in the river including crew and kayaking and that the cap design, including armoring, should consider public uses and public access at and associated with docks, marinas, etc. The CPG responded that the design will appropriately consider such infrastructure and public uses. NJDEP indicated they may have some questions on the basis of costs at the next FS Meeting.

The CPG asked if EPA had received the historical memo regarding the listed waste determination for the LPRSA, and EPA responded that yes, they had received the message and memo.

EPA noted they will take the lead on the multiple lines of evidence approach to determining completion of the interim remedy, including the use of post-interim remedy sampling data. The CPG indicated that they are also looking at this on their own, and are worried about reconciling two versions.

The CPG introduced Betsy Day from Integral, who will be taking a leading role for the CPG on adaptive management, including decision trees, decision points, triggers, and responses.

The CPG indicated they would like the opportunity to develop an adaptive management framework at least initially, using cues from various ongoing discussions with EPA and NJDEP. This would be a comprehensive adaptive management framework for the upper 9 miles of the LPRSA, including a specific decision tree for demonstrating completion of the interim remedy and another decision tree for longer-term performance monitoring and associated triggers and actions. The CPG noted that they have started work on this, but need time to expand beyond the bones of the framework they currently have, and should be ready to share a first draft of this framework in the second half of June 2019.

The CPG indicated that they agree the completion of the interim remedy should be evaluated using multiple lines of evidence, with post-interim remedy sampling being one line, but they specifically do not support the use of a null hypothesis approach to statistically interpret the post-interim remedy sampling data. The CPG noted that this will be a major sticking point within the CPG. The CPG indicated that a statistical data evaluation tool will be used, but that the actual approach to statistical evaluation should be informed by the PDI sampling program. CPG further indicated they are concerned about incorporating too much detail now and being stuck with a particular statistical tool later. EPA asked what the CPG believes the PDI would do to change any statistical evaluation methodology considered now, and the CPG indicated they do not specifically know but are concerned about any statistical test that would expose them to unreasonable risk of a false negative outcome (successfully completing the interim remedy but having a statistical test incorrectly conclude failure of the remedy), particularly after spending roughly $500 million.

The CPG asked if everyone on the team is aware of the significant sensitivities about the cost of the remedy and the possibility of a false negative outcome. The team replied that yes, these sensitivities are appreciated.

NJDEP noted that they like the direction the post-interim remedy confirmation discussion is headed. NJDEP noted that they are concerned about the uncertainty in sediment contaminant concentrations, but they recognize that the PDI will be very comprehensive and provide significant detail on the occurrence and distribution of concentrations. NJDEP asked if it would be possible to target areas with likely footprint targeting error issues earlier than the PDI, and the rest of the team expressed that the more appropriate approach would be to implement the PDI and then perform additional sampling where data variability might indicate the value of additional sampling.

The team agreed that EPA would share its thoughts on the multiple lines of evidence approach to demonstrating interim remedy success, including sediment sampling data evaluation, at the June 6, 2019 FS Meeting. The CPG indicated they should have their own concept available to share then as well.

The team discussed the CPG's revised process document. The CPG noted that they took EPA's prior comments on the relative level of detail in the process document to heart. EPA commented that the process will likely need to reflect different language than terminating the IR/FS AOC for legal reasons. EPA noted that it has no major comments on the revised CPG process document, but that additional

review time is needed and some comments may be provided. NJDEP noted that they have not had sufficient time to review the entire file, but on preliminary review they indicated that it appears their prior comments have been largely addressed. NJDEP indicated they are particularly interested in process document item #14, and they will send formal comments at a later date.

The CPG asked if a discussion could be set up about adaptive management that would include EPA's adaptive management expert(s) from headquarters. EPA noted that their adaptive management champion, Kate Garufi, is not available on June 6, when the next FS meeting is scheduled. EPA suggested that a separate adaptive management meeting might be appropriate after the June 6, 2019 FS meeting. EPA also noted that specific guidance on adaptive management should be available later in 2019, and that this should be taken into consideration.

The CPG agreed that mid to late June 2019 would be reasonable to have an adaptive management meeting. The team discussed a tentative date of the week of June 17, 2019 for this adaptive management meeting. The CPG indicated they would be prepared to talk broadly about adaptive management and offer their thoughts on demonstrating interim remedy completion at the June 6, 2019 FS meeting. EPA noted that they will share their thoughts on demonstrating interim remedy completion by June 3, 2019 so that these thoughts can be discussed at the June 6, 2019 FS meeting. The CPG noted they will be prepared to share their proposed adaptive management framework before the June 2019 adaptive management meeting.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #18
June 6, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Discuss NJDEP's comments on the CPG's May 21, 2019 version of the LPRSA process for Interim Remedy ROD1 and Final ROD2
- Discuss Adaptive Management
- Discuss the Decision Tree/Lines of Evidence – EPA Version

Meeting Minutes

DEP reported they had no comments on the May 9, 2019 (FS Meeting #16) meeting minutes. The CPG reported they would confirm whether they do or do not have comments on these minutes and will let EPA know.

EPA indicated that they have previously sent an email summarizing the meeting minutes that still need to be finalized, but have not received replies from DEP or the CPG. EPA will resend an email summarizing the outstanding meeting minutes.

General Scheduling

DEP noted that both John Wolfe and Jennifer Daley will be at least partially unavailable for the June 13, 2019 current conditions biota sampling call at the time currently scheduled (10:00 am to 1:00 pm Eastern). DEP indicated that moving the call to the afternoon may alleviate schedule conflicts. EPA and the CPG indicated they would check on flexibility to change the time of this call. The CPG noted that they have a memorandum summarizing suggested revisions to DQOs and historical and proposed current fish sampling numbers that they will share prior to the June 13, 2019 current conditions biota sampling call.

The group discussed scheduling FS Meeting #19, which would presumably be in early July 2019. July 11, 2019 was identified as the most likely date for the July 2019 FS meeting. The CPG expressed concern with having only one more FS meeting before the draft FS is submitted in August 2019 (i.e., approximately two months from FS Meeting #18). The team agreed that FS Meeting #19 would therefore be scheduled for June 17, 2019, during which interim remedy FS modeling projections and adaptive management will specifically be discussed. The CPG committed to providing information in advance of this meeting, and DEP indicated they will discuss the project internally as necessary during the week of June 10, 2019 to be fully prepared for the June 17, 2019 meeting. EPA indicated they will check to see if Kate Garufi can attend at least part of the June 17, 2019 meeting, in addition to Sun Yi (the EPA Region 2 ROD coordinator).

FS Process

The discussion of the FS process document was based on the CPG's revised process document from May 21, 2019 and DEP's May 30, 2019 comments on that document.

DEP noted that they appreciate the introductory information in the current process document.

On its comment on Item #2 from the process document, DEP indicated they have specific recommended text regarding the lines of evidence that will be weighed to determine the completion of the interim remedy. The CPG pointed to Item #14a, where language consistent with what DEP is looking for resides. DEP noted that they are content with the requested information already being in Item #14a.

Relative to its comments on Items #3.a.ii and #3.b, DEP asked if the overall timing of a remedy for the upper 9 miles would remain consistent if an interim remedy is not pursued and why, if an interim remedy were not pursued, the existing data and risk assessments would not be relied on to develop PRGs. The CPG indicated that the timing would not be the same, because several tasks were essentially cut short to finish the RI with the interim remedy in mind and significant work would be needed to pursue a more traditional remedy approach. EPA noted that given the relative level of current uncertainty in the bioaccumulation model, updated risk projections would be highly valuable after the model has been refined. DEP requested additional clarifying information be added to the process document on the traditional FS/remedy process, recognizing that this would be an alternative approach to the currently anticipated interim remedy. The CPG noted they could add information to further clarify this information.

Relative to the DEP comment on Item #6, the CPG explained that PRGs will be developed in parallel with ROD 1, prior to the interim remedy being performed, based on prior discussion and agreement. The CPG also explained that the PRGs will be based on the relationship between sediment concentrations and tissue concentrations, and sampling will be important to understanding this relationship. The CPG noted that variables that influence the PRGs and the sampling needed to better constrain the development of the PRGs need to be considered. EPA agreed with these positions, and confirmed that the PRGs may ultimately need to be refined through the course of the project if additional information is gathered that compels such refinement.

DEP indicated that their comment on Item #14 was intended to clarify the difference between sampling performed to confirm the completion of the interim remedy and other sampling performed for longer-term adaptive management. The CPG indicated that Item #14 does specifically describe post-interim remedy sediment sampling as a line of evidence, while Item #15, which is specifically described as being part of the longer-term monitoring program, describes 5 to 10 years of monitoring to support recovery projections and a final remedy. The CPG noted that Item #15 is specifically under a separate heading for the longer-term monitoring program. DEP concurred with this response.

Relative to DEP's comment on Item #16, the CPG suggested adding a parenthetical reference that risk to biota will be addressed through the actions taken to address contamination in sediment and surface water. DEP concurred with this suggestion.

Adaptive Management

The discussion on adaptive management was deferred until FS Meeting #19 (June 17, 2019).

Decision Tree/Lines of Evidence

The discussion of the approach to demonstrate successful completion of the interim remedy was based on EPA's June 5, 2019 memorandum that summarizes the multiple lines of evidence that EPA believes should be used for this purpose and that provides conceptual detail around the use of statistics to evaluate post-interim remedy confirmatory sediment sampling data.

EPA asked if the CPG had been able to review the June 5, 2019 memorandum, and the CPG responded that they had only been able to review the memorandum preliminarily and have a short discussion about it in advance of FS Meeting #18.

EPA began by describing the general purpose of the memorandum, and briefly summarized the lines of evidence expected to make up the multiple lines of evidence approach. EPA acknowledged that the relative weighting of the multiple lines of evidence has not yet been determined, but indicated that it is expected that the post-interim remedy sediment sampling and statistical data evaluation line of evidence would be given appreciable weight.

The CPG stated that collecting high density PDI data, designing the interim remedy around those data, utilizing best in industry contractors and methods, and implementing robust BMPs during the IR are better indicators of successful IR completion than the statistical analysis of the uncertain mean of post-interim remedy sediment data. EPA responded that the RAOs include numeric targets that must be demonstrated and that the interim remedy cannot be assumed successful because of the expectation that it will be successful without directly and empirically measuring the outcome. EPA indicated that it is a regulatory agency responsibility to ensure that the interim remedy is demonstrated successful using the post-interim remedy sediment sampling data, and that because others would most certainly evaluate the data in that fashion as well, it is critical that EPA take a proactive role in assessing the data. EPA reminded the CPG that there had been a group discussion with CSTAG, at the CPG's request, during which CSTAG indicated its support for collecting and statistically analyzing post-interim remedy sediment data for the purpose of evaluating attainment of numeric concentration objectives. The CPG suggested that the CSTAG discussion was based on very little sharing of information with CSTAG. EPA responded that in fact over the course of the ongoing FS process and associated meetings on the subject several internal conversations were held with CSTAG and much information was shared to assist CSTAG with considering the project and post-interim remedy needs.

EPA walked through the conceptual statistical methodology to evaluate post-interim remedy sediment sampling data, which would yield four primary outcomes and related follow-on actions based on the presumption of a PDI dataset comprised of approximately 2,000 sample points and a post-interim remedy dataset comprised of approximately 200 to 400 sample points. EPA summarized that if the PDI data, while highly unexpected, were to demonstrate that a post-interim remedy dataset of 200 to 400 sample points would not provide sufficient statistical power to evaluate the success of the interim remedy, the team would collaboratively reconsider the entire post-interim remedy confirmation sampling approach. EPA also summarized the three primary outcomes within the proposed evaluation framework: interim remedy successful; interim remedy unsuccessful; and interim remedy success indeterminate.

The CPG reiterated their low tolerance for risk that the interim remedy could result in a false negative outcome (i.e., a determination of failure through statistical testing when the numeric concentration objectives were actually met), particularly with the expenditure of a very large sum of money by the

implementing parties to perform the interim remedy. The CPG noted their objection to a post-interim remedy sediment data evaluation framework that would have any appreciable risk of a false negative outcome. EPA indicated their sensitivity to the CPG's concerns, but reiterated that empirical measurement of the numeric concentration objectives is a requirement of the interim remedy. EPA indicated that the conceptual statistical evaluation framework is intended to provide a logical framework for statistically evaluating the post-interim remedy data, and is intended to be optimal to demonstrate interim remedy success relative to the overall source control objective of the interim remedy. EPA reminded the CPG that the proposed statistical evaluation framework is not intended to be presumptively punitive, and that follow-on action from an indeterminate or interim remedy failure outcome would take the form of additional data collection and evaluation with additional in-river action being the last option for follow-on action considered. Additional in-river removal would be deemed appropriate only if it were unambiguously determined that additional source sediments remain in the river, it would be of long-term benefit towards a final remedy to perform additional removal, and it would be reasonable and feasible to perform additional removal. EPA also reminded the CPG that the PDI dataset is expected to reduce the variability within the pre-interim remedy dataset and provide further confidence in the ability of the proposed statistical framework to optimally support the post-interim remedy data evaluation and overall confirmation process. The CPG also noted that both the EPA and DEP have noted the importance of the other 3 lines of evidence, but there has been no discussion of how they contribute to the decisions regarding IR completion.

Action Items

EPA to send email to DEP and the CPG with summary of which meeting minutes are outstanding

EPA to schedule FS Meeting #19 for June 17, 2017 (all day)

CPG to compile and provide RTCs on various FS components, including the basis of costs, common engineering elements, and ARARs

CPG to provide revised version of process document based on discussion of DEP comments

CPG to provide memorandum with revisions to DQOs and biota tissue sampling numbers prior to the June 13, 2019 current conditions biota sampling call

EPA and the CPG to check on ability to move June 13, 2019 current conditions biota sampling call to later in the day to accommodate DEP schedule

DEP to coordinate an internal discussion with John Wolfe to be fully prepared for the June 17, 2019 FS meeting

DEP and the CPG to provide specific comments to EPA on the June 5, 2019 multiple lines of evidence and statistical data evaluation memorandum by June 14, 2019

CPG to provide information related to the adaptive management framework for review prior to the June 17, 2019 FS meeting

EPA to check on availability of Kate Garufi and Sun Yi to attend at least part of the June 17, 2019 FS meeting

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #19
June 17, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Adaptive Management Approach
- CPG's Revisions to Narrative IR Completion Decision Tree
- CPG IR Completion Decision Tree Figure
- IR FS Modeling Discussion (previous forwarded no changes)

Meeting Minutes

The following Meeting Minutes were accepted as final by the EPA, DEP, and CPG:

- April 11, 2019 (Current Conditions Sampling Meeting #3)
- April 18, 2019 (Current Conditions Sampling Meeting #5)
- May 9, 2019 (FS Meeting #16)
- May 22, 2019 (FS Meeting #17)

DEP suggested minor edits to the April 17, 2019 (Current Conditions Sampling Meeting #4) Meeting Minutes. EPA and CPG agreed to the edits and the minutes were accepted as final.

The June 6, 2019 (FS Meeting #18) Meeting Minutes are being reviewed by DEP and CPG.

Interim Remedy Completion

The meeting started with the participants reviewing the CPG's June 14, 2019 suggested edits to the EPA memorandum *Lower Passaic River Study Area – Determination of Successful Completion of an Upper 9 Mile Source Control Interim Remedy* dated June 5, 2019.

EPA noted they are willing to discuss the CPG suggestions, but they were received on June 14, 2019 (one working day before the meeting) and EPA needs to talk about the edits internally, before EPA formally responds to the CPG suggestions.

CPG accepted that "cost" should not be a factor in identifying the weight of each line of evidence demonstrating successful completion of the remedy. Cost had been identified as a factor by the CPG in their edits, but EPA and DEP requested it to be removed.

CPG proposed that the decision regarding the selection of statistical testing for comparing the Post IR SWAC to Target SWAC be based on the three Lines of Evidence (PDI Data/Geostatistical Analysis, IR Foot Print Development and IR Implementation (BMPs/Certification Process)). Specifically, CPG proposed that if the other three lines of evidence met specific criteria and were certified by EPA then a standard null hypothesis and the lower confidence limit would be used to compare the Post IR SWAC and Target

SWAC. CPG noted that they are committed to an appropriate post-interim remedy sampling approach (on the order of 200 to 400 confirmatory samples) regardless of the test.

CPG suggested that the fundamental question that should be asked of the interim remedy is whether there is any reason to believe that the design was not implemented effectively. EPA disagreed, and indicated that in the CPG's proposed LCL-based approach, the only answer that could be conclusively determine is that there is not certainty that the design was not implemented effectively. EPA indicated that the question that should be asked is whether, with an appropriate degree of statistical confidence, the sediment SWAC goals had been achieved. Discussion was held on the inability of CPG's proposed LCL-based statistical method to answer this question. CPG claimed the scenario as proposed by EPA (which is based on the UCL) would only be accepted by the CPG under a global settlement for the entire river. CPG asked to help find a way to do the sampling and statistics so that all of CPG will accept the plan.

CPG suggested that it is more important to look at the work that is accomplished during the interim remedy rather than the final issue of confirmation (the tail end of the activity). EPA did not disagree that the work accomplished during the interim remedy is important, but indicated that the action of the interim remedy and the confirmation need to work together.

DEP asked how one would rule out with certainty recontamination that may occur during remedy construction. CPG replied that CPG takes on the risk if the recontamination is not controlled during construction so, therefore, controlling recontamination is in the CPGs' best interest. CPG recognizes its risk associated with recontamination includes recontamination originating from the lower 8-mile RA. EPA also noted that if EPA agrees to the proposal, which includes EPA management, and achieves public acceptance of the remedy then subsequently the remedy fails, EPA also has issues.

EPA emphasized the Y factor (the multiplier on the SWAC threshold) needs to be initially defined based on the data currently available and then later refined with the PDI data.

Adaptive Management

Kate Garufi of EPA HQ joined via telephone to be involved with the adaptive management discussion.

EPA noted that the FS will contain a description of the adaptive management plan in an appendix, and it will be a general adaptive management framework. CPG noted the adaptive management plan will be about data collection, data analysis, data results, triggers, responses/actions, and modeling. CPG also pointed out that PRGs are an important component in adaptive management.

The CPG presented their adaptive management slides.

CPG pointed out the identification of working PRGs is useful because the goals will be able to identify critical factors of the CSM.

EPA replied that the presentation, mainly focused on the PRGs (including the concept of a range of PRGs), is not in line with what has been discussed in the past about adaptive management. In the future EPA expects that adaptive management will be presented in a manner that is consistent with ongoing discussions.

EPA noted that adaptive management is about technical management, but that risk tolerance is also a component of adaptive management to be included. EPA pointed out that multiple pieces of

information/data will be collected to evaluate performance and if the project gets into a situation where five to seven years of data are collected and sediment concentrations are not recovering as expected, next steps will need to be considered. Or, if recovery is acceptable in one area and not acceptable in another area, it will be important to understand what amount of uncertainty is acceptable. EPA would like to see the subsequent steps to be followed in response to various scenarios.

EPA summarized their expectations on the adaptive management as:

- A plan for next steps rather than waiting for decision points to occur, including a plan to reduce uncertainty enough to move to next steps.
- A decision point, or framework, needs to be specific so that the adaptive management phase can end and a decision on achieving a final remedy can be made.
- More details are needed on the diagnostic evaluation (e.g., what is the evaluation and what is done in response to the evaluation results).

CPG said that the concepts raised by EPA will be part of the adaptive management plan presented in the FS. In the FS, they will have more details, including decision making and next steps under different scenarios. DEP suggested that process should also be considered in the adaptive management plan.

Modeling

CPG presented information on the IR FS projection modeling.

CPG confirmed that the modeling simulations do include remediation of the lower 8 miles. At the end of reviewing model observations and results, CPG proposed to run alternatives at 85 ppt and 65 ppt using the remedy sediment transport setup.

CPG indicated that model simulations were generated assuming 3%, 1%, and 0% resuspension. EPA asked why go from 3% resuspension to 1% and not 2%. CPG noted the Hudson site has the most extensive resuspension data and in Hudson they see 1%. Another site example was noted by CPG, and they report no turbidity increases are seen. Also, CPG pointed out for the RM10.9 action they didn't observe any excursions in turbidity benchmark monitoring, indicating that there were no resuspension issues. Based on that, CPG estimated resuspension was 0-1% during the RM10.9 action. EPA pointed out that model simulations for the lower 8-mile RA show no noticeable signal in suspended solids associated with 3% release during dredging, but substantial contaminant signal.

EPA pointed out the modeling analysis is based on a relative comparison, not an absolute comparison and asked if this issue can still be an issue in a relative comparison and CPG responded, yes, the issue still exists.

EPA proposed, and CPG agreed, to do the model runs as is for now and include in the draft FS with an explanation of the implications of input variations, and then perform the additional runs and offer the results in an addendum (or the subsequent version of the FS).

EPA noted when CPG re-runs the models, they don't need to re-run for the entire remedy. They can run for four years, or so. CPG said they should rerun to about 18 years because recovery can be assessed in that period, and recovery is an interest. The EPA and CPG modelers will have a call on June 20, 2019 at 1 pm to discuss details.

Next Meeting

FS Meeting #20 will be held on July 10, 2019 at 10 am ET in Edison. The agenda is proposed to be adaptive management and interim remedy completion.

Action Items

DEP to check if they are having issues viewing Our Passaic website.

EPA to send an invite for the next meeting, which will be at 10 am on July 10, 2019 in Edison.

DEP to submit edits/comment on the interim remedy completion memorandum the week of June 24th.

EPA to setup a call to discuss interim remedy completion for July 2, 2019 at 10 am.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #20
July 10, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Continue discussing post-interim remedy verification sampling
- Discuss adaptive management plan
- Discuss FS schedule and deliverables

Meeting Minutes

EPA indicated that the meeting minutes from FS Meeting #18 (June 6, 2019) would be resubmitted to NJDEP and the CPG for review. EPA also indicated that meeting minutes from FS Meeting #19 (June 17, 2019) would be submitted for NJDEP and CPG review. All other meeting minutes from prior FS meetings have previously been finalized and will be loaded to the SharePoint site.

FS Schedule and Deliverables

The CPG indicated that they are still targeting August 12, 2019 for submittal of the draft interim remedy FS, although the adaptive management plan my lag behind that along with certain other appendices. The CPG suggested that they still do plan to talk to EPA and NJDEP about the adaptive management plan as they develop it, as there is no real template available to work from.

The CPG indicated that physical water column sampling should begin next week.

The CPG indicated that the chemical water column sampling QAPP is circulating within the CPG, and should be delivered to EPA within two weeks.

The CPG indicated that the biota sampling QAPP should be delivered to EPA on August 2, 2019. The CPG noted that they intend to begin biota sampling on September 16, 2019 and expect to work 6-day weeks over a 3-week sampling period during the biota sampling program. The CPG further noted that they have applied for a NJ fish permit, using the target catch numbers requested by EPA during prior discussion of the biota sampling scope.

Post-Interim Remedy Verification Sampling

The CPG (John Connolly) walked through its presentation supporting application of an LCL-based statistical testing framework for interim remedy confirmation. The CPG suggested that uncertainty in post-interim remedy sampling would support relying on design and construction-related lines of evidence as primary determiners before considering statistical testing of confirmatory sediment sampling data. The CPG further suggested that if the design and construction lines of evidence meet their goals, that should allow the team to presume that SWAC goals have been met instead of presuming the SWAC goals have not been met. The CPG indicated their belief that the burden of proof

should be on the agencies to demonstrate the interim remedy did not achieve its goals, rather than the CPG demonstrating the interim remedy did achieve its goals.

During its presentation, the CPG described that a broadcast application of capping material would likely lead to enhanced recovery because clean cap material would be distributed outside the target capping area. The CPG referenced a paper by Parkhurst as supporting the application of an LCL-based test, and suggested that design and construction lines of evidence provide independent evidence to apply the initial assumption that the interim remedy was successful. The CPG indicated that designing the interim remedy to a lower target SWAC simply to comply with the RAO goals would not be appropriate because it could lead to addressing areas that are not actually source areas (e.g., coarser sediments that are not really driving risk). The CPG indicated that large uncertainty in the post-interim remedy dataset could render the data not useful in evaluating interim remedy success, and further indicated that if the data variability were real, increasing sample size may not reduce the uncertainty sufficiently. EPA reminded the CPG that the UCL-based statistical testing framework previously summarized by EPA does include a mechanism to rethink the statistical testing approach if the PDI data were to suggest the UCL approach would not be reasonable.

CPG suggested that a UCL-based statistical test applying an equivalence factor may be appropriate as an alternative to the LCL-based test if the design and construction lines of evidence do not support the presumption of interim remedy success, and provided examples of additional evaluations that may be appropriate based on the UCL-based test. CPG indicated that performance goals that would support the presumption of interim remedy success might include resuspension standards (e.g., turbidity not greater than some standard some percentage of time), including chemical water column monitoring, cap placement verification, turbidity measurements during vessel movement, and minimum removal standards (e.g., addressing some required minimum percentage of design volume or area).

EPA (John Kern) walked through its presentation supporting the application of the UCL-based statistical testing framework. EPA reiterated that EPA guidance does support that at sites requiring action, it is appropriate to presume that the action was not successful until information is available to confidently determine that the action was successful. EPA also reiterated that the UCL-based statistical testing framework takes into consideration inherent uncertainties in calculating SWACs and the non-absolute nature of the RAO SWAC objectives. EPA indicated that, if an LCL approach were used, minimum detectable differences would need to be developed.

EPA summarized its procedure for calculating the Y-factor (margin of equivalence) using the existing site data, including varying assumptions regarding footprint targeting errors and post-interim remedy confirmatory sediment sampling size. EPA illustrated the variability in calculated SWAC when the true average is 85ppt 2,3,7,8-TCDD for 500 simulations, and further illustrated Y-factor derivation for various combinations of targeting errors and sample size (500 simulations of calculated SWAC when true average is 85ppt 2,3,7,8-TCDD), setting the Y-factor at a threshold of 95 percent of calculated SWAC UCLs complying. These illustrations demonstrated that the Y-factor can be established such that when the true average is equal to the RAO goal, and with a reasonable number of post-interim remedy samples and a realistic assumption regarding footprint targeting errors, the UCL would be less than the modified RAO goal (Y times the goal) with sufficient statistical certainty (e.g., 95%).

The CPG expressed a concern regarding the EPA's UCL-based testing framework and how the design and construction lines of evidence would be integrated. The CPG specifically suggested that the EPA's June 5,

2019 memo ignored the design and construction lines of evidence. EPA noted that the June 5, 2019 EPA memo was intended to summarize all of the lines of evidence, including the design and construction and the statistical testing lines of evidence, but only to discuss the statistical testing line of evidence in and of itself in detail. EPA indicated that the purpose of the June 5, 2019 memo was not to suggest that the design and construction lines of evidence did not fit within the statistical testing framework. EPA noted that the June 5, 2019 memo can be revisited to integrate the design and construction lines of evidence specifically into the statistical testing line of evidence and related decision making.

NJDEP offered that they consider the design and construction lines of evidence to be essential, and that a statistical testing approach is moot without meeting the goals of the design and construction lines of evidence. NJDEP indicated they are in general agreement with the EPA's UCL-based testing framework and the resulting outcomes (success, failure, indeterminate) and potential follow-on evaluations/actions as previously expressed in the June 5, 2019 EPA memo. NJDEP noted that they are still not able to comment fully on the Y-factor derivation and its implications, pending discussions within the agency, and also indicated that they generally take a more conservative view of attaining the RAO SWAC goals. NJDEP specifically noted that they believe the infill PDI sampling may be a valuable tool in minimizing footprint targeting errors and understanding and controlling data variability.

The CPG asked for direction from EPA regarding the acceptable threshold of false negative for the Y-factor application (i.e., what level the Y-factor should be established at such that X% of calculated SWAC UCLs would comply with the equivalence level).

When asked when the CPG thought the Y-factor should be determined, John Connolly responded that at the time of design would be appropriate so that the Y-factor could account for areas that will not be remediated because of necessary offsets (e.g. utility crossing or bridge piers).

Adaptive Management

There was insufficient time to discuss the adaptive management plan.

Next Meeting

FS Meeting #21 will be held via conference call on July 22 or July 24, 2019. EPA and the CPG will discuss the date and time and EPA will then send a meeting invitation to the team.

EPA reminded the team that a public meeting regarding the project will be held in Clifton, NJ the evening of July 25, 2019.

Action Items

NJDEP to have internal discussions regarding interim remedy verification.

EPA to provide the CPG with direction regarding the acceptable threshold for Y-factor determination.

EPA to revisit the June 5, 2019 memo to incorporate design and construction lines of evidence into the statistical methodology and decision making.

EPA to send an invite and agenda for the next FS meeting.

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Diamond Alkali OU 4 FS Conference Call
July 24, 2019

Location: Conference Call

Participants:

EPA and Team:
- Diane Salkie
- Michael Sivak
- Beth Franklin
- Andrew Bullard
- Aaron Frantz
- Ed Garland
- John Kern
- Scott Kirchner
- Keegan Roberts
- James Wands

NJDEP and Team:
- Anne Hayton
- Myla Ramirez
- John Wolfe

CPG and Team:
- Tal Ijaz
- Rob Law
- Bill Potter
- Mike Barbara
- John Connolly
- Marcia Greenblatt
- Sue Harden
- Peter Israelsson
- Bill Locke
- Hank Martin

Agenda

- General Items and Meeting Minutes
- Adaptive Management
- Decision Tree/Lines of Evidence – EPA Version

General Items and Meeting Minutes

EPA confirmed with CPG the draft Feasibility Study (FS) is scheduled to be submitted for review on August 12, 2019. Also, EPA confirmed for the CPG the Adaptive Management Plan and the Post Remedy Sampling Decision Memorandum, which will be provided as appendices of the FS, do not need to be submitted with the draft FS. These two items can be submitted in the version of the FS subsequent to the draft FS.

The CPG suggested minor edits to the meeting minutes from FS Meeting #18 (June 6, 2019) and FS Meeting #19 (June 17, 2019) and EPA and DEP accepted the edits. The edited minutes from both meetings were accepted. Also, the DEP and CPG indicated they are reviewing the minutes from FS Meeting #20 (July 10, 2019).

Adaptive Management Plan

The CPG gave a presentation on their proposed approach to developing an adaptive management (AM) plan (see attached presentation). The CPG noted the presentation will be expanded into a narrative and shown in an AM plan in the FS. The CPG indicated that the proposed approach is structured around

pieces of the overall program that are likely to involve key decision points, particularly where there is uncertainty and additional information will be acquired.

EPA noted that a very draft EPA guidance for preparing an AM project management plan was sent to CPG on July 23, 2019 and this draft guidance (EPA stressed that the document was very draft) could be used by the CPG as a reference in developing their plan.

In the slide deck on AM Element 1, PRG/RG Development and Refinement, DEP noted they do not consider this as an AM element. DEP suggested AM Element 1 should be deleted and AM Element 2 moved to AM Element 1. CPG responded PRGs can evolve over time and the plan needs to be flexible to respond to these possible changes. For example, the state of the science may evolve over time (as an example, the carcinogenicity of dioxin may change), thus, changing a PRG or RG.

DEP pointed out the question on slide 9 regarding recovery progressing toward protective levels is a different question than asked in AM Element 3 on slide 5. DEP further noted the AM Element 3 question is an important question. The CPG clarified that the questions asked within AM Element 3 and AM Element 4 are different questions, and that the question on slide 9 is actually aligned with the question in AM Element 4 (and not AM Element 3) on slide 5.

Decision Tree/Lines of Evidence – EPA Version

John Kern dropped off the call at 1 pm ET, which was during the AM presentation by CPG. Prior to Mr. Kern leaving the call, EPA checked if participants had question for him. CPG said they did not have questions. DEP said they do have questions, and the participants agreed to handle the questions by email.

EPA noted they edited the memo *Lower Passaic River Study Area – Determination of Successful Completion of an Upper 9 Mile Source Control Interim Remedy* (referred as the Decision Framework) in response to DEP and CPG comments. DEP replied they are still reviewing the backup statistical information provided by EPA and this review could have an impact on their reply to the Decision Framework. In response to an EPA question, DEP replied they are focused on the review and providing their input, but they don't have a specific timeline for when their input will be available.

EPA showed the file with the edits made in response to the CPG and DEP comments. This file will be shared by EPA to DEP and the CPG after the meeting.

EPA reviewed the file with the participants and started by stating the most substantive change may be to describe the statistical lines of evidence and incorporated them as EPA thinks they logically fit. Also, EPA noted a quantitative weighting scheme has not been proposed, and may not be necessary, but will be discussed among the team as suggested in the revised memo. EPA stated that in a prior meeting the CPG said the statistical testing would be less important than the other lines of evidence. The revised memo still puts substantial weight on the statistical testing and incorporates the other lines of evidence within the post-IR data evaluation framework.

The discussion on the performance monitoring on page 4 was expanded. On bullet 2, CPG agreed that changing the parameter to evaluate dredging success to contaminant mass as opposed to dredging area or volume is a good change.

EPA noted, on pages 4 and 5, the UCL and LCL were each set at 95%. Prior to this version, the values were not specified. The CPG asked if the revised language could be interpreted as there is a 90% confidence interval with 5% on the upper side and 5% on the lower side. EPA did not agree with CPG's rephrasing of the language, but the CPG believed they understood the narrative.

On page 5, CPG requested an upper limit be added to the narrative to complement "not less than 400 individual sampling locations" as a post-IR sample size. EPA pointed out that this is a process and the number may change based on the PDI data. DEP added they thought it was premature to identify sample quantities now. EPA said a parenthetical could be added at the end of the sentence that specifies the current value is based on the RI data. CPG suggested change "currently available data" to "RI data" and note the actual number will be informed by the PDI sample.

The possible outcomes of the IR based on the statistical testing and the likely resulting actions were reviewed.

CPG asked for clarity on the likely follow on actions within the "Not Conclusively Complete" outcome, were the pre-IR and IR LOEs to not all have been performed satisfactorily (for instance, not all performance measures complied with relevant performance standards), and if those follow on actions would be different than if the pre-IR and IR LOEs had been performed satisfactorily. EPA responded that the follow on actions would likely be the same in either situation, with an ultimate assessment of potential remaining sources and the removal of such sources if present, if removal would improve the outcome of the IR, and if removal were feasible.

CPG noted including the amount of material that is encountered and if an action is needed would be beneficial. EPA recognized the value of that suggestion, and noted the memo was set up to provide guardrails and not dive into the multiple specific quantities and combinations that could be encountered.

DEP stated reducing the SWAC is important to kick-starting the recovery and the other lines of evidence are intrinsic to the program, for example, a robust PDI is very important. DEP stated that as-builts are an important indication of whether or not the remediation goal are likely to have been met. The CPG asked if the DEP agrees with the memo's decision framework, and the DEP responded that they need to re-read what is written and give a formal response.

DEP noted they considers 85 ppt more than a symbolic number. They noted if the SWAC is higher then recovery would be slower, and if the SWAC is lower, then recovery would be faster. However, DEP also noted the IR should not remove clean material unnecessarily. DEP expressed that if the value of "Y" is 2, then an acceptable SWAC may be as great as 170 ppt, which could lengthen recovery by a factor of two.

DEP indicated they consider 85 ppt to be a bright line but they are considering this decision memo and evaluating, and they are having internal conversations. EPA highlighted the timeframe and noted things are coming along quickly, the FS is to be submitted next month. Also, EPA offered if DEP has any questions, they should ask EPA. DEP indicated that reviewing the Decision Framework is a high priority for them. EPA asked participants to review the clean version of the Decision Framework memo that EPA will be sending out today. EPA noted the draft FS is coming in on August 12, 2019 and if someone wants to reach out to EPA for questions, they can do that.

EPA summarized that within the approximately 90 acres that form the footprint to achieve 85 ppt (based on RI data and conditional simulation map #37), the average 2,3,7,8-TCDD concentration is between 2,500 and 2,600 ppt. To target 75 ppt, approximately 6 acres would be added to the footprint, within which the average concentration is approximately 230 ppt. To target 65 ppt, another approximately 8 acres would be added to the footprint, within which the average concentration is approximately 185 ppt. The CPG reminded the group that the original IR proposal was structured around a RAL of 300 ppt as a means to control sources. In one map (map 37) applying a RAL of 300 approximately corresponds to a SWAC of 85 ppt, but applying a RAL of 300 ppt results in variation in SWACs above and below 85 ppt across the 100 conditional simulation maps.

Action Items

DEP and CPG to review the minutes from FS Meeting #20 (July 10, 2019).

EPA to distribute edited *Lower Passaic River Study Area – Determination of Successful Completion of an Upper 9 Mile Source Control Interim Remedy* to the DEP and CPG after the call.

DEP and CPG to review the edited *Lower Passaic River Study Area – Determination of Successful Completion of an Upper 9 Mile Source Control Interim Remedy.*

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #21
September 16, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- Adaptive Management Plan – IR FS Appendix D
  - Adaptive elements, key questions and potential outcomes/responses
    - Adaptive Element 1 – Development of PRGs and Final RGs
    - Adaptive Element 2 – Overall System Response
    - Adaptive Element 3 – Recovery Assessment to Attain PRGs/RGs

- Interim Remedy Completion Evaluation Framework – IR FS Appendix H
  - Four lines of evidence to support the source control IR
    - LOE 1 – Delineation and mapping of sources and areas subject to erosion
    - LOE 2 – Remedial design
    - LOE 3 – IR implementation
    - LOE 4 – SWAC attainment
      - Process to evaluate post-remedy data (i.e., the Y value)
      - Testing for SWAC attainment (use of reverse null hypothesis; tolerance for false negatives)
  - Decision Tree

- IR FS – Main Document
  - Discussion of any comments and questions

- Additional Meetings

Meeting Minutes

EPA, NJDEP, and the CPG concurred that the meeting minutes from FS Meeting #18 (June 6, 2019) and FS Meeting #19 (June 17, 2019) were previously accepted as final (i.e., during the July 24, 2019 FS-related conference call). EPA indicated these meeting minutes will be uploaded to the LPRSA SharePoint site. NJDEP and the CPG indicated they are still reviewing the meeting minutes from FS Meeting #20 (July 10, 2019). All other meeting minutes from prior FS meetings have previously been finalized and uploaded to the SharePoint site.

IR FS Discussion

EPA informed the CPG that on the morning of September 16, 2019, prior to FS Meeting #21, EPA and NJDEP met to further discuss the post-IR completion determination process. EPA also indicated that NJDEP had previously provided comments on the CPG's proposed Adaptive Management framework (i.e., after the July 24, 2019 FS-related conference call), and EPA will forward those comments to the CPG.

EPA asked what the source of potential discrepancy is that is preventing the CPG from submitting the Adaptive Management and IR Completion appendices to the IR FS. The CPG indicated that they are seeking assurance that there is consensus from EPA and NJDEP on the foundations of the adaptive management and IR completion frameworks. EPA noted that they wish to review the appendices to provide comments and come to agreement. NJDEP noted that they are close to finishing their review of the IR completion framework concept.

NJDEP commented that they would not be able to support a Y-factor for the IR completion framework that is too high. The CPG noted that they also do not like a high Y-factor, as it reflects a poor understanding of the system. Nonetheless, the CPG also noted that the Y-factor should not be 1, but something higher than that. EPA, NJDEP, and the CPG agreed that the Y-factor should be established based on the PDI sediment data.

NJDEP suggested that other summary statistics should be used to support an IR completion determination. The CPG asked how such summary statistics would specifically be used. The CPG also noted that any discussion of other summary statistics is new and has not previously been considered. NJDEP indicated that they do not have a specific proposal for how to use other summary statistics, but they will talk more about the morning meeting with EPA and the discussion during FS Meeting #21 and provide specific information to EPA and the CPG.

The CPG noted that what they need as part of the IR FS is to have a process laid out and agreed to that would support the determination of critical controlling parameters (e.g., the Y-factor) using the yet to be collected PDI data, to avoid reshuffling the deck later and developing a new post-IR completion determination framework. EPA generally agreed with this position.

With respect to adaptive management, EPA commented to the CPG that standard elements of a CERCLA process, such as developing a remedial design, should not be considered adaptive management. EPA noted that the IR FS should acknowledge that not all activities being performed or to be performed as part of the IR would constitute adaptive management.

EPA expressed its disappointment with the adaptive management framework proposed by the CPG continuing to include the use of a range of PRGs. The CPG noted that they would like to consider the initial PRGs to be “working PRGs”, to deemphasize “preliminary” in PRG. EPA noted that they do not support using a range of PRGs, as it is problematic for a variety of reasons, including the presentation of risk-based cleanup to stakeholders. The CPG countered that they have discussed PRG development extensively and believe that a range of PRGs is substantiated by the level of uncertainty in several critical FWM parameters. EPA suggested that uncertainty in critical FWM parameters could be addressed for each parameter (e.g., through the use of a statistic, such as the 95UCL, to describe that parameter from a range of potential values), such that a point estimate for a PRG could still be developed. EPA reminded the CPG that there has already been agreement that PRGs may be revisited and revised as additional site information is generated.

Ultimately, the CPG indicated that they would deliver the Adaptive Management appendix of the IR FS (Appendix D) after reviewing the NJDEP comments on the July 24, 2019 presentation. The CPG also noted that they do not plan to submit the IR Completion Framework (Appendix H) until receiving NJDEP’s feedback on the use of other summary statistics. NJDEP indicated they would discuss this and provide feedback as soon as possible.

Additional Meetings

The team discussed holding an in-person meeting the week of October 7, 2019 to discuss agency comments on the draft IR FS. The team agreed to hold this meeting at 10am on October 8, 2019 at the EPA's Edison, NJ office.

EPA reminded the team that the CSTAG meeting is coming up on November 19, 2019, and that November 20, 2019 is set aside for stakeholder engagement.

Action Items

EPA to send out invitation to October 8, 2019 FS Meeting #22.

NJDEP to discuss internally the use of summary statistics in the post-IR completion framework, and provide feedback as soon as possible.

CPG to provide IR FS Appendix D (Adaptive Management).

Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
Meeting #22
October 24, 2019

Location: EPA Region 2 in Edison, New Jersey

Participants: See attached attendance list

Agenda

- **Comments on the Draft FS**
  The comments on the Draft FS were submitted by EPA to the CPG on October 18, 2019. The comments the CPG wanted to focus on during the meeting, and that were discussed at the meeting, were identified by the CPG on October 22, 2019. The comments focused on during the discussion are grouped into four categories:
  - Range of PRGs
  - Source Definition
  - Cost Estimates
  - Additional Comments
- **Schedule of Upcoming Activities**

Comments on the Draft FS

Range of PRGs

The CPG stated they understand Comment 1 (i.e., PRGs should not be developed as ranges but rather as single point estimates), and they will address it and not propose a range of PRGs in the FS. They explained that adaptive management should help reduce uncertainty in the variables to focus the PRGs in a scientifically supportable way before RGs are selected. EPA acknowledged PRG revision is part of adaptive management and it is likely that PRGs will change as the process progresses.

Source Definition

EPA explained their desire to avoid a quantitative discussion, especially given the uncertainty of any potential value to define "source." The CPG felt the proposed definition that is in the EPA comment set on the Draft FS is too subjective and presents a source definition based on the alternatives themselves. EPA stated that the current definition of source biases the FS too strongly toward the 85 ppt alternative without consideration of other alternatives that may aid river recovery. The CPG noted the approximately 300 ppt concentration level for 2,3,7,8-TCDD is only a working number which could be revised based on PDI data and stated that the level is useful for defining source and non-source sediments, which would presumably be remediated actively and passively, respectively.

NJDEP voiced their support for EPA's original written comment and further elaborated that "source" is relative within the river, influences on concentrations in the river (including from the Lower 8 Miles) are highly uncontrolled at this time, and risk-based goals are not yet defined. NJDEP stated the IR FS should rely on the RAOs to dictate "source."

The CPG stated RAO 1 clearly ties "source" to 85 ppt. EPA noted that RAO 1 intends to achieve "not more than 85 ppt", and, therefore, lower concentrations may potentially be targeted as source. EPA stated it is worthwhile to see if lower SWAC alternatives lead to meaningfully greater recovery acceleration. The CPG presented Slide 1 (see attached slide deck) to show projections of gross 2,3,7,8-TCDD erosion flux, post-IR implementation, for the various alternatives. They noted that the 85, 75, and 65 ppt alternatives demonstrate very similar levels of source control from the figure, with only about 1 or 2 grams of contaminant flux difference at the end of 18 years. They stated the figure clearly shows 85 ppt achieves source control and the lower alternatives do not provide much incremental benefit. They noted that they can further focus on other metrics to attempt to differentiate the FS alternatives. EPA noted that the revised definition of source (as presented in the EPA comment set on the Draft FS) does not prevent distinguishing the alternatives.

NJDEP stated that a large part of the State's position is the expectation that the IR may be the last active remediation in the river, so they are interested in lower SWACs sooner to achieve future risk-based goals. The CPG noted that, from the model, there is little if any difference predicted between the 65 and 85 ppt alternatives, and the differences generally converge over time. They stated a lower SWAC does not necessarily lead to faster recovery and whether additional remediation will be needed beyond the IR will depend on the risk-based goals that are eventually established and whether they are attained within a reasonable timeframe. NJDEP noted that the actual rates of recovery will not be known until after IR implementation. The CPG noted that detailed modeling during and following the IR will help refine the estimates, and progress towards goals can be managed adaptively.

The CPG agreed to revise the IR FS based on the revised description of source rather than the quantitative 300 ppt threshold. EPA agreed with this approach. The CPG asked EPA to review comments (such as Comment 43) that state there is a clear difference in recovery potential between the 85, 75, and 65 ppt alternatives in light of the analyses presented by the CPG during the meeting.

Cost Estimates

The CPG stated that some comments on cost estimate revisions do not aid in comparison of alternatives. For example, they stated that the monitoring costs are small relative to the overall costs of alternatives. They would rather focus time and effort on evaluation of alternatives rather than evaluation of cost. They requested clarification on which costs they should focus on revising. EPA stated they would look at the cost comments again and, if necessary, develop a specific request regarding the details/backup of the cost calculations.

Regarding Comment 11, EPA clarified that the no action alternative should present no costs, including no costs for the 5-year review. They noted that the 5-year review is not a response action, so it should not be included in costs for the alternatives. CPG understood the clarification.

Comparative Analysis

Regarding Comment 7, EPA explained that they are interested in more structure and more metrics in the comparative analysis to better aid the reader in coming to a well-supported conclusion. They requested additional discussion of the differences, or lack of differences, between the alternatives.

The CPG asked for clarification on what was meant by "exposure reduction." EPA clarified that it was language from the May 29, 2018, CSTAG memo. EPA stated that, rather than discussing risk, exposure reduction can be used (because it is directly related to SWAC reduction).

NJDEP noted that the SWAC differences of the alternatives serve as different starting points for monitored natural recovery. They do not agree that the 75 and 65 ppt alternatives have identical recovery and are excessive remedial alternatives relative to the 85 ppt alternative. They stated that the uncertainty bands on the modeling show the importance of initial conditions but do not support the statement that the performance of all active alternatives is identical. EPA supported exploring any differences in concentrations, if they do exist.

CPG requested clarification on which depth interval should be considered for computations of contaminant mass reduction. EPA acknowledged that data in the top 6 inches may be the most useful, since subsurface concentrations have much higher uncertainty (subsurface data are sparser than surface data). They noted that input from CSTAG would also be requested on this calculation.

Regarding Comment 9, EPA noted that they want the FS ready to present to the CAG, so the FS should include more visuals for the alternative comparisons. The CPG acknowledged that the goal was for the IR FS to be understood by everyone. EPA noted that more metrics and more visual representations of results are helpful tools for the evaluation of alternatives. The CPG asked if the kinds of figures in the draft CAG presentation (SWAC, duration, mass removal, cost, etc.) are what EPA wishes to see in the IR FS. EPA confirmed they are and noted that the draft presentation has been uploaded to the Our Passaic site. The CPG stated that they would send draft figures of other information they believe may be useful to present in the IR FS.

Regarding Comment 264, the CPG noted that the comparative analysis summary table is visual, but that the numeric comparisons are located elsewhere in the feasibility study. EPA stated that they would like to be able to see the differences of alternatives better in the summary table. The CPG stated that they can elaborate on the weighing of the various criteria. EPA stated that it may be worthwhile to refine the increments expressed in the rankings in the comparative analysis table, possibly down to 10%. EPA also stated that the comparison charts discussed for Comment 9 (see paragraph above) can feed into how the alternatives are presented in the summary table. The CPG noted that the importance of each criterion is subjective. They also noted that worker risk should be focused on effort hours rather than volumes to make sure that the workers are the primary focus when it comes to safety.

Subtitle C vs. D Disposal

Regarding Comment 6, the CPG stated that it is reasonably conservative to assume disposal at a Subtitle C facility because they have not found a Subtitle D facility that will accept sediments from the Passaic River. EPA said that an acceptable compromise would be to discuss the pros and cons of disposal at a Subtitle C or D facility, explain why Subtitle C is assumed and why specific allocation cannot be performed at this time, and include a sensitivity analysis of cost for all dredged material going to a Subtitle D facility to give the reader perspective on the potential impacts to costs. The CPG agreed to the compromise.

Appendix E – Lessons Learned

Regarding Comment 319, the CPG noted that addressing the difficulties noted in Appendix E will be covered during design. EPA stated that revisions to Appendix E should include introductory language that acknowledges the issues but also acknowledges that they can be overcome.

Project Duration

Regarding Comment 347, the CPG noted that the differences in durations of the various alternatives are based on applying a dredge rate to the different dredge volumes. They stated that the difference in duration for the dredge alternatives is approximately 9 months and that a sensitivity analysis would not produce significant changes to comparison of the durations due to the similarities in dredge volumes. EPA agreed that, based on the explanation given by the CPG, Comment 347 could be disregarded.

Ratios of Contaminant Levels

Regarding Comment 123, the CPG noted that that reason the Newark Bay PAHs did not have a statistically significant difference from concentrations in the Upper 9 Miles was because of the variance of the data set. EPA was satisfied with the explanation.

Sediment Recovery

The CPG asked for clarification on Comment 273. EPA noted that they are looking for more discussion of the figure referenced in the discussion.

Issues That Can Be Addressed Regarding PRG Development

The CPG stated that it may be difficult to describe distributions for some inputs to the bioaccumulation model, which affect development of PRGs, but issues (and ways to address them) to overcome the difficulty include:

- Uncertainty could be reduced by tagging studies where fish are exposed
- Structure of the food web could be reduced by stable isotope studies
- Transfer efficiency across gut wall could be investigated

EPA commented that ranges of bioaccumulation input values may be evaluated if distributions can't be described.

Schedule of Upcoming Activities

NJDEP acknowledged that they intend to submit comments on Appendix D – Adaptive Management the week of October 28, 2019.

EPA stated that they do not need responses to the Draft FS comments within 30 days of the CPG's receipt. They stated the focus by the CPG should be revising discussion of source and ranges of PRGs (removing the "range of" part but including more discussion on the uncertainty of PRG values). EPA stated that the next draft of the FS would not be expected until the beginning of 2020, after a response is received from CSTAG. The CSTAG response is expected approximately six weeks after the CSTAG/NRRB meeting to be held November 20 and 21, 2019.

The CPG requested a debrief from EPA's CSTAG meeting to get started on those topics before a response is formally sent. EPA agreed that they could update the CPG on the major topics discussed in the CSTAG meeting.

EPA is preparing a presentation for the upcoming November 20 and 21, 2019, CSTAG meeting. They intend to discuss the FS as it currently stands, topics under review, resolutions from meetings, etc. They

will also provide a crosswalk of Appendix H with a summary of the positions of EPA, NJDEP, and the CPG for CSTAG to comment on.

Appendix D was submitted by the CPG on September 25, 2019 and Appendix H was submitted by the CPG October 22, 2019, two days before this FS Meeting #22. EPA said they can provide big picture comments to CPG on Appendix D and Appendix H in a call the week of October 28, 2019. Written Appendix D comments are expected to be sent to the CPG the week of November 4, 2019. The EPA/NJDEP team will coordinate on a date for Appendix H to be reviewed and comments submitted.

In response to an EPA request, the CPG stated they can provide revised language to discuss the source definition and PRGs prior to the CSTAG meeting.

Action Items

NJDEP to submit Appendix D comments to CPG during the week of October 28, 2019.

CPG to call EPA the week of October 28, 2019, to discuss the revisions to the source language and discussion of PRGs.

EPA to schedule a call with the CPG the week of October 28, 2019, to discuss big-picture Appendix H comments.

EPA to submit Appendix D comments to CPG during the week of November 4, 2019.

EPA to call CPG, following the CSTAG meeting, to give an informal debrief prior to receiving formal written comments from CSTAG.

EPA to review comments, such as Comment 43, that state there are clear differences between recovery potential of 85, 75, and 65 ppt alternatives.

CPG to send draft alternative comparison figures prior to their inclusion in the revised IR FS.

FS Meeting #23
Conference Call Summary
Lower Passaic River Study Area Interim Remedy Feasibility Study
February 18, 2020

Agenda

Discuss the draft FS, in particular:

- Meeting Minutes
- Schedule
- Source Definition
- FS Comments
- Adaptive Management

Location: Conference Call. The meeting was originally scheduled to be in-person and it was titled as FS Meeting #23. However, the in-person meeting was then changed to a conference call due to travel constraints by some parties, but the title was retained.

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner

CPG:
- Mike Barbara
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelsson
- Rob Law
- Bill Locke
- Hank Martin
- Bill Potter

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- Rasa Bubnyte

NJDEP:
- Anne Hayton
- Jay Nickerson
- Myla Ramirez
- Anthony Cinque

USACE:
- Beth Franklin

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

Introduction

At the beginning of the call, meeting participants agreed the FS activities are ongoing and the agenda for this call is limited until the project progresses more.

EPA Region 2 noted they are working on replies to the CSTAG Recommendations on *Operable Unit 4, the Lower Passaic River Study Area. 17 Mile Remedial Investigation/Feasibility Study, Interim Remedial Action – Draft Feasibility Study and Overall Cleanup Strategy* dated January 31, 2020 and because EPA

Management has not reviewed the responses yet, the responses cannot be discussed on this call. Also, the EPA noted Draft Feasibility Study Appendix D comments are being prepared and should be delivered to CPG soon. EPA suggested the call could be used to discuss the EPA evaluations of the FS response to comments dated February 13, 2020 and the CPG's thoughts on the Source Definition and Adaptive Management Plan suggestions, which have previously been discussed with the EPA.

The CPG responded they were not able to discuss the FS comments because they have not discussed them internally. CPG noted they were comfortable with the Source Sediments Definition changes the EPA provided on February 7, 2020.

Some conversation was initiated by the DEP on suggestions they have for the Source Definition. The NJDEP identified some areas of concern, including de-emphasis of RAO1 attainment and biota exposure, and offered a revised alternative source definition. EPA noted they would need to review the DEP suggestions further after the call as EPA is seeing the suggestions for the first time today. After further discussions between EPA and DEP, suggested edits would be sent to the CPG.

DEP stated they had no comments on FS Meeting Minutes #22 from October 24, 2019. Therefore, the minutes are accepted as final.

CPG noted the FS modeling metrics results, in response to FS Comment #7, are being prepared and they (CPG) need to look at the results before they submit them to EPA.

Action Items:

EPA will schedule a call for February 25, 2020. The participants agree to holding a call to discuss the Source Definition and a few FS Comments, then in early March (day and time to be set later) a detailed discussion on the FS Comments could be held because the responses to the CSTAG Recommendations would be available.

EPA and CPG will talk about setting up a meeting to discuss current conditions sampling.

EPA will review the DEP comments on the Source Definition and submit suggestions to CPG.

EPA will submit Appendix D comments to CPG.

EPA will post FS Meeting Minutes #22 to the SharePoint site.

CPG will review the modeling metrics file and submit the evaluation to EPA.

FS Meeting #24
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
March 5, 2020

Agenda

- EPA Comments dated February 27, 2020 on Draft IR FS Appendix D
- EPA Responses dated March 2, 2020 to CSTAG Recommendations

Location: EPA Region 2 Edison office (Room 111)

Participants: See participants list attached.

Appendix D Comments
A general discussion was held before specific comments were discussed. CPG noted the Appendix D comments were well written and agrees with the Adaptive Management Plan (AMP) being restructured around the three adaptive management elements, IR Design and Implementation, System Response, and System Recovery. The CPG noted they can respond to the restructuring readily, but they are still absorbing the Appendix D comments. They also noted today they are asking for comment clarifications. DEP noted they are looking at the Appendix D comment set, they agreed to the structure change recommendation, and early next week they will give feedback to EPA.

Comment #1 – In reply to a CPG question, EPA confirmed a revision to the AMP should be submitted by the CPG in the next version of the FS. EPA noted, where possible, more detail should be added in this forthcoming version (in response to comments); EPA acknowledged that not every detail can be added now, because certain details will not be available until particular issues are resolved through ongoing FS discussions.

Comment #3 – CPG stated the adaptive management program was designed to address data gaps and reduce uncertainties because of a lack of data, and that not too much emphasis should be put on the model when a lot of data are being and will be collected. The CPG noted if the refined model projections do not agree with expectations, the CSM needs to be evaluated or the model utility needs to be reassessed. EPA agreed with this position, and suggested a diagnostic assessment may be in order if the refined model does not predict a response consistent with the expectations of the IR. As Comment #3 reads, EPA pointed out the current models predict less of a response to the IR than anticipated and a refined model should project results that are more consistent with the CSM. CPG agreed they would evaluate what the models predicts. The CPG did not want the IR design or implementation to be delayed by the re-evaluating models, the CPG wants to leave open all possibilities at the IR stage including that the model is not a tool to be used as conceived. EPA suggested that refining the model should not slow down the IR design process. The CPG paraphrased a statement the DEP made and agreed with the statement, that undue weight should not be put on the model and the model should be used as a tool to get to the best outcome.

Comment #34 – In reply to a CPG question, EPA instructed CPG to acknowledge in the FS that interim thresholds for fish tissue will be used, but details on the thresholds do not need to be included. EPA highlighted, as has been discussed previously, this project will have sediment-based remedial goals. In

the future, one way to develop interim fish tissue thresholds would be for EPA/DEP to provide consumption levels that would be run through the risk assessment. However, the specific method to develop the thresholds is not needed in the next FS version.

Comment #55 and #58 – CPG asked how to define and develop reasonable timeframes. Meeting participants agreed the CPG would lay out a process that leads to a determination of a reasonable timeframe and acceptable recovery rate and EPA would provide comment. The CPG commented the plan can present timeframes during RD, but those timeframes may need to be revisited when long term monitoring is being conducted. CPG plans to submit a revision to the AMP with the revised FS, they will not submit an interim deliverable.

CSTAG comment 5e (Region 2 response agrees with CSTAG that an AMP should unambiguously indicate when decisions will be made and on what basis) – In response to the CPG asking for the detail being requested, EPA responded the plan should be less ambiguous on when sampling would occur and when decisions will be made based on those sampling data. Also, in addition to identifying details, items that cannot be detailed at the present time should be identified and the reason for deferring this detail added. In short, the Plan should be specific where possible and generalities should be included where specifics aren't available yet (because they will come out in design and even into monitoring).

EPA agreed to collaboration and meetings to facilitate the finalization of the FS in two months. However, EPA does not have a specific schedule in place currently for FS finalization. EPA, DEP and CPG agreed that working together will facilitate finalization of the FS. CPG indicated they will start working on revising Appendix D.

CSTAG Recommendations and EPA Region 2 Responses

EPA mentioned a new CSTAG Charter has been released. In the charter, four meetings are identified and the third meeting for this Lower Passaic River project was held in November 2019. On April 30, 2020 CSTAG will likely be in New York City for a Newtown Creek Superfund Site meeting and a suggestion was put on the table for the fourth Lower Passaic River project meeting to be held during that same timeframe. The goal of advancing the FS so that the fourth meeting can be held in this timeframe will continue to be discussed between EPA, DEP and CPG. EPA will forward the new charter to the CPG.

1a – No discussion on recommendation or response.

1b – Discussion on this recommendation was brief, because it is about the source definition and EPA and DEP are currently discussing the language for the definition. DEP pointed out, for the record, DEP is not in agreement with the current source definition and it is with their management. EPA replied that DEP management had been informed earlier in the day that EPA is moving forward with the current definition for the reasons discussed with DEP.

1c – EPA noted an analysis is needed quantifying the expected impact on the SWAC due to potential erosion of sediment overlying subsurface sediment with a 2,3,7,8 TCDD and/or total PCB concentrations between a factor of 1x and 2x the surface RALs. EPA suggested a simple analysis is needed to fulfill the requirement of the recommendation and response. Without knowing the scope of this analysis, CPG replied they could not agree to doing this type of analysis but they will discuss further and get back to EPA. EPA said if CPG proposes the analysis is not needed, then, EPA may consider the suggested rationale for not doing it. EPA noted the Region is accountable for responding to the CSTAG

recommendations and that CSTAG will follow up with the Region on how recommendations were implemented. EPA also noted that some recommendations can be resolved now and some may need to be resolved later; however, this recommendation (1c) needs to be resolved now.

1d – No discussion on recommendation or response.

2a – No comment from EPA or CPG. DEP said they are not sure they want to defer a discussion of smaller DUs to a final remedy and believe they can look more closely at the need for smaller DUs when the PDI date are available. EPA replied to DEP by making the point that there is a benefit to considering the single reach (RM 8.3 to RM 15) in developing the SWAC because smaller sub-reaches could result in higher sub-reach-specific RALs compared to the RAL needed to attain the SWAC goal across the upper 9-mile reach (goal is for RM 8.3 to RM 15). DEP understood the point but remained uncertain in their opinion of deferring a discussion of smaller DUs to the final remedy.

2b – Participants agreed the language for addressing sources located in the RM 15 to Dundee Dam reach needs to be revised. EPA noted they need to figure out the best approach for this, and it will include receiving recommendations from the EPA attorney on an acceptable approach, whether the language is within an existing RAO, a new RAO, or a decision process outside the RAOs. The CPG suggested a footnote would be the simplest and would greatly reduce the need to revise the draft FS compared to introducing a new RAO. EPA agreed to propose the approach.

3a – No discussion on recommendation or response.

3b – In response to CPG's inquiry on details necessary for the construction performance monitoring program, EPA replied they recognize all details cannot be identified now, but there are some things that could be identified and shown in Appendix H. The forthcoming Appendix H comments from EPA to CPG will ask for details/information that was discussed in the July 24, 2019 memo, *Lower Passaic River Study Area – Determination of Successful Completion of an Upper 9 Mile Source Control Interim Remedy*. EPA noted that the Appendix H comments will be generally consistent with the language of the July 2019 memo.

Also, all participants agreed weighting of evidence needs to be discussed and agreed on. EPA stated the actual lines of evidence (LOE) weighting probably will come out in RD, but a discussion should be in the FS. EPA described to CPG to add some details in the FS to note the weighting is coming, but it won't be in the FS. Participants agreed the weighting needs to be in place before the weighting is needed/applied. The CPG noted we need to be careful which weights are specified now, because early specification may prohibit meeting goals when the sampling is done.

3c – EPA stated they recognize that there are two rates or error (false negative and false positive) and they are not necessarily equal. The CPG appreciated EPA's recognition.

DEP pointed out false positive error is important, and that they think equally important relative to false negative error. DEP noted they hope this IR is a final in-river action. EPA replied the AMP addresses the possibility of further action being needed; if EPA identifies that additional work in the river is needed, then EPA will direct the additional work to be done. Also, EPA stated because this is an IR, EPA has a limit on what can be asked. EPA stated they recognize the risk to an IR is that EPA will need to direct

further action and EPA noted it is important to acknowledge the balance between risk tradeoffs during an IR versus a final remedy.

DEP had a question if EPA is setting a policy constraint on the Y value. EPA replied there is no upper constraint on Y by policy. EPA continued that the Y value would be derived by the data and the recipe for deriving Y. EPA noted that while they do not consider an "optically high" Y value to be an appropriate consideration in constraining Y as a matter of policy, there is an outcome in the post-IR decision-making procedure to reevaluate the decision-making framework if the underlying data variability and resulting Y value are technically inappropriate. Also, CPG noted they have the option to go back into the river to collect more samples to tighten up the Y value.

3d – No discussion on recommendation or response from EPA or CPG. DEP expressed some interest in the CSTAG comment on sampling before construction is complete. EPA explained the response based on the concern for potential recontamination before construction completion, which provides justification for synoptic sampling and not sampling before construction is complete.

4a – No discussion on recommendation or response.

4b – CPG noted RM10.9 monitoring data are being received and evaluated and will be used to inform the FS and IR. The CPG will share the validated data with the EPA when it is available, before the report is written. The CPG are not waiting to use the data/information until the report is written.

4c – CPG said they are drafting some principles on dredge to clean and will submit to EPA for consideration. In response to a brief discussion on what some considerations may be for dredge to clean, DEP commented they think CSTAG is referring to dredging to sediment contaminant concentrations that are not impacted by the original OU4 contamination source. Another thought mentioned was considering a physical contact (e.g., bedrock) for dredge to clean.

5 – No further discussion on recommendation or response. Adaptive Management was discussed earlier in the meeting.

General Topics

CPG asked a general question on what EPA thinks CSTAG's response will be if EPA diverges from the CSTAG recommendations. EPA replied CSTAG will want to know how EPA dealt with the recommendations and how the recommendations/responses are incorporated into the FS, IR, and/or longer-term project. CSTAG may want to see parts of the next FS version (e.g., Appendix D and/or H) to check on the incorporations.

A discussion was held on Current Conditions Sampling. Participants agreed a meeting is needed to discuss the sampling to be conducted in 2020, and beyond. CPG stated they are trying to collect samples at specified flow rates, which was the program started in 2019. They need three more events to complete that phase. CPG and EPA agreed the sampling (water and biota) data should be evaluated to determine if refinements to the sampling program are warranted, and all data from previously implemented sampling should be available in April. CPG noted they will start working on biota collection permits soon and they plan to be in the river in August, so long as gill net waiver request is approved by DEP. CPG will eventually prepare a data summary report, but for this data set evaluation, the EPA team will work with the data that has been received to date to help plan the next sampling events. A sampling meeting should be set for April.

Next Meeting

The next FS workgroup meeting (FS Meeting #25) was set for March 25, 2020 from 10:30 am to 1:30 pm.

Action Items

EPA*:*

- Set up FS Meeting #25 for March 25, 2020 from 10:30 am to 1:30 pm
- Distribute minutes for FS Meetings #23 and #24 for review
- Email new CSTAG charter to OU4 Team (EPA group, DEP and CPG)
- Send comments on Appendix H of the IR FS to CPG
- Develop an approach to respond to CSTAG recommendation 2b, addressing potential source areas from RM 15 to Dundee Dam
- Share HDR's calculations regarding the effect on the SWAC if non-dredged areas erode and expose sediment concentrations ranging between 1x and 2x the surface RAL

NJDEP:

- Review Appendix D comments

CPG:

- Submit dredge to clean proposal to EPA
- Submit new IR FS modeling and metrics results to EPA

FS Meeting #25
Conference Call
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
March 25, 2020

Agenda

- Appendix H comments
- CPG's new modeling and metrics results for the IR FS
- Follow up (or any missed) discussions on CSTAG recommendations (in particular 1c, 2b and 4c)

Location: Conference Call

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner
- Keegan Roberts

CPG:
- Mike Barbara
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelson
- Rob Law
- Bill Locke
- Hank Martin
- Bill Potter
- Doug Reid-Green

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- James Wands

DEP:
- Anne Hayton
- Jay Nickerson
- Myla Ramirez

USACE:
- Beth Franklin

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

Introduction

EPA welcomed participants to the call and appreciated their attendance during this time when people are working remotely due to stay at home orders in response to the COVID-19 pandemic. EPA noted, and CPG concurred, work on the IR FS needs to continue and weekly conference calls may be set up to continue to discuss and revise the IR FS.

DEP brought up the Appendix D comments they emailed to EPA on March 19, 2020 and EPA noted responses to the comments were provided to DEP on March 20, 2020. DEP reiterated their comments and noted their main comments were prioritizing PRG development and improving correlation between Adaptive Elements 1 and 3. EPA, in summary, reiterated their March 20, 2020 response and said because PRG development and potential refinement is in Element 3 and IR design is in Element 1, it does

not prevent those activities from occurring simultaneously; the element numbers do not indicate a chronological order.

Appendix H Comments

The first set of comments (Comments 3, 5, 12, 13, 14, 16, 17, and 18) discussed were grouped by the CPG because they wanted to request clarification on the meaning of the comments.

Comment 3 – CPG asked what detail is being requested in the last sentence of the comment. CPG noted they can certainly add a few sentences, but they are not at the point they can commit to certain things. CPG noted when detail is added, those details need to be vetted within the CPG and it adds time to the schedule. EPA replied that generally as much detail as possible is being requested while recognizing that certain details will not be possible until the IR design, after pre-design data are available. EPA noted that when other comments are discussed today, those discussions will help identify the level of detail being requested and, in addition, future meetings may be used to hash out those details.

Comment 5 – CPG asked what is meant by "relevant depths of interest…" at the end of the second paragraph. EPA replied that relevant depth of interest relates to the convergence of erosion depth from evaluation of bathymetric data and concentration information (i.e., concentration above a RAL) from the PDI to establish areas subject to RAO 2. EPA also noted that a similar type comment is in the FS comment set and that better defining the PDI program (e.g., identifying sample locations and depths) would be responsive to this comment. CPG noted their working assumption now for the PDI would be to sample 0-0.5 ft, 0.5-1.5 ft and 1.5-2.5 ft (and likely a greater depth). CPG stated the program in the FS would only be a proposal and that the program may change in IR design. CPG also described the current understanding of erosion depth from existing bathymetric data. EPA, in response to a CPG question, clarified that the use of "depths" (plural) at the end of the second paragraph does not imply an expectation of sampling depths and intervals varying from location to location.

Comment 12 – CPG initiated a discussion on their proposed geostatistical interpolation approach. DEP noted the preference would be for the CPG to use a similar interpolation framework that has been used at the site and adjust it with the spatial relationships suggested by new data, and further suggested the CPG should consider the time involved in applying the geostatistical approach relative to project schedule. CPG replied by indicating they would do just what DEP suggested, and build an approach with the PDI data using the old framework. Additionally, EPA suggested to present additional detail of the process by presenting the questions that will be answered with the geostatistics.

Comment 13 – A discussion was held on the bathymetry data sets that should be used to understand areas of erosion. CPG stated they would use the 2010, and later, data sets. CPG noted that they would be uncomfortable using the 2008 data because of a bad datum. CPG indicated they could use the 2007 data, but are wary of using the 2007 data because of its chronological separation from 2010. EPA pointed out that the 2008 data have been relied on previously, with adjustment to account for the datum issue, and that there should not be a perceived issue using 2007 and 2010 data when it is already understood that overall interpretation of bathymetric data will include a substantial gap between the last historical survey round (2012) and the most recent survey (2019). After some discussion with EPA, the CPG agreed to use the 2007 and 2008 data in addition to the 2010, and later, data sets and CPG will discuss the uncertainty of the data sets when they are used.

Comment 14 – In response to the comment, CPG noted they can provide a conceptual description on evaluating uncertainty based on other sites but they cannot provide additional detail until the data are collected. DEP replied the CPG response is acceptable and the DEP also noted this discussion could be used to describe sampling, followed by a second round of sampling to refine cut lines or fill in gaps to improve statistical determinations. CPG agreed a second round of sampling (i.e., the infill sampling) would be conducted if it resolves uncertainties and reduces targeting errors and said they can add text to this extent to respond to the comment.

Comment 16 – EPA clarified for the CPG that capturing the language and spirit of the March 8, 2019 memorandum would meet the requirements of the comment. EPA noted including what has been discussed is sufficient because all details may not be resolved until all pre-design data are available.

Comment 17 – EPA agreed to the CPG's response to add language summarizing how VE will be used during the design process, that EPA will be aware of the VE component of the design process and that EPA will review/approve recommendations from the VE study.

Comment 18 – CPG presented their concern on including details for performance monitoring. EPA indicated that anticipated components of the IR performance monitoring have previously been discussed and these anticipated components should be described in the appendix. CPG said they can add additional framework to the appendix to describe the anticipated types of performance monitoring, but they can't provide all detail. EPA emphasized good performance monitoring and collecting a robust data set, because the data can be used to demonstrate achieving an important line of evidence. In response to a CPG question about the use of "most critical" in the fourth line of the comment, EPA clarified that performance monitoring may not need to be described in the FS as the most critical but that selecting a qualified contractor should itself not be described or implied as most critical. All parties agreed the weighting of evidence will be fleshed out more in future meetings.

Comment 2 – In response to CPG, EPA replied that the term "statistical power" could reasonably be inferred to relate to "power" in the traditional statistical sense, but that the intent of the comment is actually to suggest better constraints on the confidence limits around the SWAC estimate and not a quantitative power analysis to inform an approach to a second round of sampling.

Comments 26 and 38 – Discussion postponed to the next FS meeting so that the IR FS Modeling Metrics Update can be presented today.

Comment 28 - Discussion postponed to the next FS meeting so that the IR FS Modeling Metrics Update can be presented today.

IR FS Modeling Metrics Update – (see attached slide deck)

CPG presented the slides and summarized each of the metrics which show a significant reduction step achieved with Alternative 5, followed by some impact from the additional increment represented by Alternative 2 and then much smaller changes for the additional increments represented by Alternatives 3 and 4. At the end of the presentation, DEP noted that the modeling results appear to show Alternative 4 achieves greater reductions in SWAC and those reductions persist over the 10-year period evaluated and these reductions are important to DEP.

Some additional discussion followed, but the audio quality was poor so EPA, DEP and CPG agreed to end the conference call and continue the conversation during a subsequent call, possibly next week.

Follow up discussions on CSTAG recommendations (1c, 2b and 4c) – No discussion held on today's call.

Action Items

- EPA to set up the next conference call possibly for April 2
- EPA to possibly set up a modeling conference call

FS Meeting #26
Conference Call
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
April 2, 2020

Agenda

- IR FS Schedule – Items needed for the next version of the IR FS
- Modeling Metrics
- RAO 2
- River Mile 15 – Dundee Dam
- Appendix D
- Dredge to Clean - tentative

Location: Conference Call

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner
- Keegan Roberts

CPG:
- Mike Barbara
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelsson
- Rob Law
- Bill Locke
- Hank Martin
- Bill Potter
- Doug Reid-Green

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- James Wands

DEP:
- Anne Hayton
- Jay Nickerson
- Myla Ramirez

USACE:
- Beth Franklin

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

IR FS Schedule – Items needed for the next version of the IR FS
EPA presented a list of IR FS topics that have been discussed and need to be addressed. The topics from the EPA's presentation were grouped into three categories around the IR FS schedule as presented below.

<u>1. Topics to be fully developed in the IR FS (requires more immediate consideration):</u>
- Definition of source sediments for RM 8.3 to RM 15

    - Establish functional basis of action for IR
- Addressing area above RM 15
    - Establish enforceability of actions above RM 15
- Defining dredge to clean
    - Establish method for applying concept of dredge to clean to support decision-making
- Approach for understanding impact of erosion on SWAC
    - Establish quantitative understanding of this uncertainty
- Acceptable false positive error rate for reverse null approach
    - Establish key component of recipe for deriving Y values for statistical testing framework (complements previously accepted false negative error rate of 5%)

<u>2. Topics to be developed to every extent possible in IR FS (requires more immediate consideration):</u>

- Weighting scheme for LOEs for IR Completion Evaluation Framework
    - Substantiate use of information in decision-making process
- Defining remaining source/actionable remaining source for IR Completion Determination Framework
    - Support decisions related to IR completion or needed follow-on action

<u>3. Topics to be developed after IR FS (requires less immediate consideration):</u>

- Pre-design sediment sampling approach
- Geostatistical interpolation approach for pre-design sediment data
- Performance monitoring approach for IR
- Post-IR sediment sampling approach

On the dredge to clean item, EPA noted there is an interest from EPA HQ to have details in the IR FS on dredging sediments to a depth that is considered clean. EPA also explained CSTAG has requested more details on dredge to clean and more information on responding to changes during the Adaptive Management program (IR FS Appendix D). CPG said they are working on principles that would address the dredge to clean item and EPA noted this item will need to be reported on in detail in the next CSTAG briefing. EPA noted Appendix D is on the agenda and will be discussed later in the meeting.

CPG noted the definition of source sediments is key to writing the comparative analysis of the IR FS, so agreement on the definition is necessary so as not to delay the development of the document. DEP replied they are working on the source sediments definition with EPA and they hope to have a reply on the current version to EPA by the middle of next week. A discussion on the current status of the source sediments definition ensued and, in summary, EPA believed the current version responded to DEP's interests and DEP stated they were still concerned that the first sentence of the definition was absent of language indicating elevated concentrations are a source of exposure to biota. EPA pointed out their disagreement of having biota exposure as a component of the IR FS definition because there is no metric in the IR for biota exposure reduction. CPG said they are concerned DEP and EPA have exchanged definition changes and have not included CPG. EPA said they wanted to be in agreement with DEP before sharing the words with CPG. However, EPA shared the current definition with CPG during the meeting so that CPG could see the edits that EPA has considered in response to DEP's feedback.

In response to the list of 11 topics, CPG said they have worked on binning these activities also and they agree with the list and prioritization EPA has presented. CPG also noted one item to add is the uncertainty analysis that will be presented in Appendix H, and CPG suggested the item be part of the

second item (geostatistical interpolation approach) under "Topics to be developed after IR FS". EPA agreed with the topic addition.

Modeling Metrics

CPG presented bulleted items explaining, in summary, that the lower SWACs of the larger footprint alternatives provide little additional benefit and the modeling metrics indicate that the three alternatives (Alternatives 2, 3, and 4) meet the source control objective (see attached slide deck). CPG prepared the presentation to respond to previous DEP comments that DEP sees about a 25% SWAC reduction between Alternatives 2 and 4 and DEP considers this reduction would result in a biota uptake reduction also.

In response to CPG's presentation, DEP reiterated their comment on the SWAC reduction and continued that the model results show the reduction is persistent, so the biota uptake reduction would also be persistent. DEP said to CPG that the RAO1 SWAC goal does represent a reduction to biota exposure, the new baseline at the end of construction is important, and DEP would like the SWAC change considered in the comparative analysis. DEP said the reduction in timeline to meet future risk-based goals is also important and they want to see this action as a one time in-river action.

CPG replied to DEP that their points are important and significant, but the three alternatives being discussed (Alternatives 2, 3, and 4) each meet the goals of the IR, and because the biota impact cannot be measured at this time, the IR goals must be used. The CPG continued with summarizing the overall upper 9-mile approach of eliminating the issues of contaminated sediment moving throughout the system by addressing high concentrations (the primary goal of the IR), then measuring effect on the system, including biota, then going back to the river if additional action is needed.

In response to CPG, DEP agreed that risk reduction is not measurable at this time, but exposure reduction is measurable. The CPG said that exposure reduction is also uncertain, for instance because the dredged areas may extend into areas that have no exposure issues (i.e. more dredging does not imply more exposure reduction). CPG said they do not want to make statements in the IR FS that they technically cannot defend.

Participants agreed the modeling metrics discussion would not be resolved today. EPA said the slides on modeling metrics that have been submitted by the CPG will not be reviewed, but the formal text and figures on modeling metrics that are forthcoming from the CPG as part of the IR FS will be reviewed and commented on by the EPA and DEP.

RAO 2

CPG presented their analysis of the SWAC sensitivity to exposure of subsurface sediment due to erosion, with 2,3,7,8 TCDD concentrations varying between 1x and 2x the surface RAL (see attached slide deck). This analysis was an expansion of the EPA analysis provided to the CPG on March 16, 2020. The analyses were performed to respond to CSTAG Recommendation 1c. The CPG's analysis, like the EPA's analysis, concluded that the hypothetical exposure of subsurface sediment with 2,3,7,8 TCDD concentrations between 1x and 2x the surface RAL does not increase the SWAC to above the SWAC target in each respective alternative (Alternatives 2, 3, and 4). The DEP said they were reviewing the analysis provided by EPA and would review the CPG's analysis to check if it met the CSTAG's recommendation and DEP will reply to EPA by the next FS meeting.

River Mile 15 – Dundee Dam
EPA presented slides (see attached slide deck) on proposed revisions to the RAOs to address RM 15 to Dundee Dam. The key slide was RAO1 with a new footnote incorporating RM 15 to Dundee Dam into the RAO. EPA noted there are two pieces to this action of addressing RM 15 to Dundee Dam: 1) the administrative action of adding the footnote and 2) the considerations for defining the size of actionable area from RM 15 to Dundee Dam. DEP said they currently do not have any objection to this approach of incorporating RM 15 to Dundee Dam into the RAO, they think it is a feasible way to proceed.

CPG replied they have ideas of incorporating RM 15 to Dundee Dam into the RAO. One idea is to have a SWAC goal for that reach. EPA stated the current SWAC goal for RM 8.3 to 15 is approximately an order of magnitude reduction in SWAC and asked the CPG if their idea includes an order of magnitude reduction in SWAC for above RM 15. CPG did not offer a suggested SWAC goal for the reach. Another option offered by the CPG is to extend the RM 8.3 to RM 15 area some distance above RM 15, essentially expanding the area for which the RAO1 goals would apply. The additional area of interest as proposed by the CPG is between RM 15 and 15.8, because above RM 15.8 sand and gravel deposits dominate and elevated concentrations would not be expected. EPA replied that extending the reach to above RM 15 would need a re-write of the RAO, which would be a difficult task and is probably not feasible.

EPA stated we are looking for a simple, logical framework that achieves the purpose and will not need substantial time for negotiation. EPA pointed out the current footnote does not necessarily mean an action will take place.

CPG noted that based on all data collected to date above RM15, the likelihood of finding elevated TCDD is low, but elevated PCB may be found (i.e., the RAL exceedance may be PCB, not TCDD). Another suggestion made by the CPG was to stay agnostic on the data set (i.e., the PDI sediment data) that we do not have yet and use the data to guide the decision making when the data are available. Thus, the CPG suggested not defining source in the footnote, but stating source(s) will be defined based on data collected in PDI. CPG will compile their suggestions on addressing sediment in RM 15 to Dundee Dam and submit to EPA and DEP.

Appendix D – CSTAG response update
EPA stated that a CSTAG representative and EPA HQ representative recently provided EPA feedback on Appendix D and the three adaptive elements proposed by EPA for the appendix. EPA explained EPA HQ is developing adaptive management plan guidance and EPA HQ and EPA Regions are aiming to be consistent with their adaptive management plans at sites across the country. EPA HQ wants the adaptive management framework of Appendix D to align with the EPA HQ current approaches to adaptive management. EPA noted, in summary, that EPA HQ thinks all components of the adaptive management framework should exist under a controlling adaptive goal of "what needs to be done at this site to get to clean". EPA further explained that this could be accomplished by rolling the content of the Adaptive Management Plan under what was previously conceived as System Recovery.

In response to a DEP question, EPA said these suggested changes consist of repackaging existing content. EPA is not asking for components of the adaptive management framework to be fundamentally changed.

CPG said the suggestions are understood and they will develop an approach to meet the requested changes.

Dredge to Clean

This item was not discussed. It will be discussed at a subsequent meeting.

Next Meeting

CPG will check if they are available to meet in a conference call with EPA and DEP on April 7, 2020 from 10 am to noon.

Action Items

- EPA to send invite for next FS conference call. Date and time contingent upon availability of participants.

- DEP
    - Reply to EPA on current edits to source definition. If EPA does not hear from DEP by April 3, 2020, they will contact DEP early in the week of April 6 to achieve resolution on the definition.
    - Review the RAO2 analysis presented by CPG (in addition to the analysis done by EPA earlier). DEP will respond by the next FS meeting.

- CPG and DEP will review the proposed RAO1 footnote and adaptive management slides.

- CPG
    - Submit a suggested footnote for RAO1 covering source above RM 15 to Dundee Dam.
    - Review the suggested changes to the Adaptive Management Plan.

- EPA to possibly set up a modeling conference call.

FS Meeting #27
Conference Call
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
April 16, 2020

Agenda

- Source Definition
- Addressing Area Above RM 15
- RAO2 Erosion Analysis – Feedback from EPA and DEP
- False Outcome Error Rate and Balancing N and Y
- CPG's Revised Appendix H Decision Tree – Feedback from EPA and DEP
- Agenda for Next Meeting

Location: Conference Call

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner
- Keegan Roberts

CPG:
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelsson
- Rob Law
- Bill Locke
- Hank Martin
- Bill Potter
- Doug Reid-Green
- Matthew Stanton

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- James Wands

DEP:
- Anne Hayton
- Allan Motter
- Jay Nickerson
- Myla Ramirez

USACE:
- Beth Franklin

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

Introduction

EPA welcomed the participants. EPA said three meeting minutes have been sent to the DEP and CPG for review: FS Conference Call (February 25, 2020); FS Meeting #24 (March 5, 2020), and FS Meeting #25 (March 25, 2020). Additionally, EPA said minutes for FS Meeting #26 (April 2, 2020) will be sent soon to DEP and CPG for review. DEP and CPG said they would review the four sets of minutes and provide comments to EPA.

Source Definition

The version of the source definition with footnote that was developed on April 8, 2020 and discussed with DEP, then subsequently shared with the CPG on April 13, 2020 was accepted. CPG provided edits to the definition on April 15, 2020 but EPA indicated they would not make further changes. CPG accepted this. The April 8, 2020 source definition with footnote that was accepted by EPA, DEP and CPG is:

> ***Source sediments*** *are defined in this IR FS as sediments having elevated concentrations. These sediments have a low potential for recovery, and act as a reservoir for potential migration of contamination to surface water and biota[1], thereby inhibiting overall recovery in the system. Sediments with low recovery potential are defined as those with 2,3,7,8-TCDD and/or total PCB concentrations greater than those associated with current water column particulate concentrations. Water column particulates influence system recovery through transport and deposition (additional information related to contaminant transport and the influence of depositing water column particulates on recovery is provided in Section 2.4.3 and Section 2.6, respectively). Addressing source sediments would greatly reduce the 2,3,7,8-TCDD and total PCB SWACs (and reduce SWACs for other collocated contaminants that are addressed by the remediation footprint), which would in turn reduce concentrations on suspended water column particulates, reduce concentrations in surface sediments where water column particulates are deposited, reduce sources to biota, and accelerate system recovery. If an IR is implemented, source sediments would be defined during design based on the selected target SWACs, pre-design sediment sampling data, and associated RALs.*
>
> *[1] Concentrations in surface sediment represent an exposure to biota. Because the specific relationship between sediment concentrations and tissue concentrations is not certain, it is not certain whether contaminant concentrations in biota would be reduced in direct proportion to the reductions in sediment concentrations. However, it is expected that ecological exposure and tissue concentrations would be reduced over some time frame in response to an IR, which is expected to result in a reduction in ecological and human health risk.*

Addressing Area Above RM 15

EPA, DEP and CPG agreed that incorporating the remediation objectives for the area above RM 15 to Dundee Dam should be accomplished using a footnote to RAO 1. CPG explained they would want credit for remediating above RM 15, by way of including the area remediated above RM 15 in the post-IR SWAC calculation. Using an example, they continued if ½ acre is removed from above RM 15, that ½ acre should be included in the SWAC estimate. CPG explained their proposal is to include the dredged area in the estimate, not the area of the reach where the dredged area is located. EPA voiced concern that adding an area above RM 15 into the SWAC calculation may result in increasing the RAL for the RM 8.3 to 15 reach. DEP noted that this is their concern also, they said they do not want the addition of area above RM 15 to affect the exposure reduction that would be achieved below RM 15 without the additional area from above RM 15. CPG believes including the dredged area above RM 15 in the SWAC calculation is appropriate because the area to be remediated above RM 15 is expected to be small and a small area won't substantially change the SWAC and, if a larger area to be remediated is discovered above RM 15, then it should be addressed. EPA said the discussion was helpful to understand CPG is interested in including remediated areas (i.e., not reach lengths) in the SWAC and will evaluate the CPG's suggestion. EPA reiterated that their position is it would not be acceptable to include an entire segment of the river above RM 15 or otherwise include unremediated areas above RM 15, but that the proposal to include discrete areas above RM 15 in the post-IR SWAC calculation would be considered. A

comment was made to consider adding these ideas on the RM 15 to Dundee Dam reach in another section of the FS, with only a brief footnote to RAO 1. However, the consensus was to cover all vital components in the RAO 1 footnote. EPA will develop a suggested footnote for discussion between EPA, DEP and CPG. EPA will review the RAO 1 footnote provided by CPG and prepare a response for the next FS meeting.

RAO2 Erosion Analysis - Feedback from EPA and DEP
EPA stated the CPG's refined RAO2 analysis presented during FS Meting #26 on April 2, 2020 is appropriate and should be included in the FS. DEP agreed with EPA's statement and DEP said they concluded the CPG analysis addresses CSTAG's recommendations (specifically Comment 1c) and noted the analysis should be in the FS. DEP pointed out that additional chemistry data and bathymetric data will be collected after the FS and asked if the additional data will be used to assess erosional areas and if the multiplier of 2x will be reevaluated in the RD. EPA stated that there is an existing agreement with CPG that the erosional area and multiplier will be revisited with the new data.

False Outcome Error Rate and Balancing N and Y
EPA gave the presentation Establishing Error Rates and Balancing Post-IR Sample Size and Y (see attached slide deck). The presentation concluded with a summary of expectations:

- False outcome error rates
    - False negative = 5%
    - False positive = 10%
- Post-IR sample size
    - 800 sampling locations and application of compositing should bound expectations for post-IR sediment sampling
- Y factor
    - Factor of 1.5 should bound expectations for thresholds to evaluate IR success
- Protections
    - With pre-design sediment data, expectation is significantly lower data variability, better control of targeting errors, and ability to keep Y factor lower
    - Inability to keep Y factor at 1.5 or lower would signify potential issue with pre-design data (and IR footprint)
        - Consider possibility of reasonably small increase in post-IR sample size (1,000 sampling locations with compositing) to adequately constrain Y
        - Reconsider post-IR data evaluation framework

CPG noted the presentation was very helpful and is generally in line with their thinking. CPG noted when trying to decide on N and Y, they would use an iterative method: start with 400 sampling locations and 3 composites and check Y factor. If Y factor less than 1.5, they would stop at 400 sampling locations. If not less than 1.5, they would continue increasing N until 1.5 is achieved. CPG noted 1.5 is a maximum, and they believe that PDI data will likely support a Y-value that is below 1.5.

DEP noted they appreciated the conversation and understand the reason the Y factor is important. DEP voiced their concern of being certain the true SWAC is not a high number. DEP also said from their point of view, 1.5 is still a high number for Y and should not be the default or the goal, as DEP views it in CPG's proposed methodology. DEP pointed out it is important to them for smarter sampling, like infill sampling during the PDI, be performed to tighten the estimate of SWAC. CPG replied they have proposed supplemental PDI sediment sampling that would support reducing target errors of the IR footprint

mapping. Also, EPA, in response to a DEP comment, said stratified sampling could be performed, like sampling in shoals vs the channel, and sampling locations may be further refined with bathymetry data. CPG replied their idea of stratified sampling would be to differentiate between remediated and unremedied areas in addition to stratifying based on geomorphology and findings of the PDI.

EPA and CPG agreed with the presentation and discussion and the CPG can move forward with writing Appendix H, including the proposed constraints on setting N and Y. DEP agreed CPG can proceed with writing Appendix H and the language on setting N and Y. DEP said they are encouraged by the presentation and they will discuss it as a team.

CPG's Revised Appendix H Decision Tree – Feedback from EPA and NJ

EPA explained the Figure 2 (Decision Tree) from the first draft of Appendix H should be used, and not the revised Appendix H Decision Tree recently provided by the CPG. EPA explained that Appendix H Comment 2 was directed at the narrative supporting the decision tree, not the graphical depiction of the decision tree itself. EPA noted they are working on a lines of evidence weighting methodology and this methodology would be used to revise Appendix H. DEP has no comments. All agree, at the next meeting weighting and lines of evidence will be discussed.

Other

Summer 2020 Biota Sampling – EPA and DEP requested CPG to copy Diane Salkie and Jay Nickerson on the sample collection permit application to be submitted by the CPG this week. Also, EPA noted they will communicate with DEP on the waiver for gillnets. CPG stated that the scientific collection permit application would be sent to DEP this week.

Next Meeting

EPA will set up a call for FS Meeting #28 to be held next Thursday April 23, 2020 from 1030 am to 130 pm. The proposed agenda for the next meeting:

- Weighting of Lines of Evidence
- Dredge to Clean
- Remaining Sources (Appendix H and above RM 15)

Action Items

EPA

- Send minutes for FS Meeting #26 (April 2, 2020) to DEP and CPG for review.
- Send invite for FS Meeting #28 for April 23, 2020 from 1030 am to 130 pm.
- Review RAO1 footnote provided by CPG and prepare a response for next meeting.

DEP

- Review and provide comments to EPA on meeting minutes: Conference Call (February 25, 2020); FS Meeting #24 (March 5, 2020), FS Meeting #25 (March 25, 2020), and FS Meeting #26 (April 2, 2020).
- Review the EPA presentation made today (April 16, 2020) on *Establishing Error Rates and Balancing Post-IR Sample Size and Y* and confirm agreement with information in presentation.

CPG

- Review and provide comments to EPA on meeting minutes: Conference Call (February 25, 2020); FS Meeting #24 (March 5, 2020), FS Meeting #25 (March 25, 2020), and FS Meeting #26 (April 2, 2020).

FS Meeting #28
Conference Call
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
April 23, 2020

Agenda

- Dredge to Clean (CPG presentation)
- Decision Tree comments and weighting the lines of evidence (EPA presentation)
- Assessing potential remaining sources after IR (EPA presentation)
- Footnote for RM 15 to Dundee Dam comments (EPA presentation)

Location: Conference Call

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner

CPG:
- Mike Barbara
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelsson
- Rob Law
- Bill Locke
- Hank Martin
- Bill Potter
- Doug Reid-Green

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- James Wands

NJDEP:
- Anne Hayton
- Jay Nickerson
- Myla Ramirez

USACE:
- Beth Franklin

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

Introduction
EPA welcomed the participants. EPA noted DEP reviewed the three meeting minutes files distributed by EPA and DEP had no comments on the minutes for FS Conference Call (February 25, 2020) and FS Meeting #25 (March 25, 2020) and one comment was made on the minutes for FS Meeting #24 (March 5, 2020). CPG said they reviewed the minutes and have added their comments; for the FS Meeting #24 (March 5, 2020) minutes, they added their comments to the file containing the DEP comment. CPG will submit the comments to EPA.

Dredge to Clean – CPG Presentation

CPG made the presentation *Principles for Dredging Without Capping (Dredge-to-Clean)* (see attached slide decks and supporting WORD file). During the presentation, CPG reported the lithology of each core

is logged and native material is identified visually where encountered. This method was used in the RI and is suggested for the IR PDI. CPG said native material was encountered in many of the cores in the RI and the native material depth does vary: from the RI samples in RM 8.3 to 15, in approximately 20% of the samples native material was encountered shallower than 2 ft, in another approximately 10-15% of the samples, native material was encountered in the 2-3 ft range, and the remainder of samples are below a depth of 3 ft. In response to a DEP question, CPG said they do not have analytical results of the native material, which is a reddish-brown clayey material. EPA mentioned some chemistry possibly was analyzed in the native material of the lower 8 miles. CPG said they could check the lower 8-mile database to see if the chemistry is reported for native material and, if so, the CPG could check on the concentrations. CPG continued with noting some of the COCs have a different loading history than PCBs and 2,3,7,8 TCDD, thus the concentrations of these other COCs would be difficult to estimate with correlations even if total PCB and 2,3,7,8 TCDD concentrations were available. Therefore, making a determination if sediment is "clean" from a chemical perspective considering all COCs is complicated.

EPA will review the presentation and prepare a response for the next FS meeting.

Footnote for RM 15 to Dundee Dam comments - EPA presentation

EPA made the presentation *Approach to Address Area Above River Mile 15* (see attached slide deck). In the beginning of the presentation, EPA noted a general principle that if an area above RM 15 with concentrations above the RAL (developed for RM 8.3-15) is identified it should be included in the SWAC calculation at the post-IR concentration if it is included in the IR footprint, or at the unremediated concentration, if it is not included in the IR footprint. Also, EPA explained that the effect of including a remediated area above RM 15 on the RAL for below RM 15 was assessed by EPA and it was concluded adding the area into the SWAC calculation would not have a significant effect (i.e., the RAL change would be inconsequential). In reply to a CPG question on bullet 1 on slide 7 (What constitutes a source area "that is inhibiting recovery of the LPR" above RM 15), EPA replied that the factors assessed in RM 8.3 to 15 should presumably be the same factors assessed above RM 15. CPG said the other two bullets of the slide (What constitutes "feasible to address" for an identified source area above RM 15 that is inhibiting recovery of the LPR? and In what manner will a source area above RM 15 that is inhibiting recovery of the LPR and is feasible to address "be addressed as part of the IR"?) are design questions. EPA noted the questions related in these bullets were drawn from the CPG footnote suggestion of the previous FS meeting. In response to a CPG question, EPA replied that if areas below RM 15 are not remediated because they are too small, they should still be included in the post-IR SWAC calculation.

CPG and DEP will review the presentation for the next meeting.

Decision Tree Comments and Weighting the Lines of Evidence - EPA presentation

EPA made the presentation *Proposed LOE Weighting Approach for IR Completion Evaluation Framework* (see attached slide deck). EPA said the presentation suggests a sequential LOE and generally each of the LOEs receives 100% weight at the time of its use.

In reply to a CPG question on what are the implications of the LCL test (i.e., why does it matter?), EPA replied it matters that the statistical outcomes (indeterminate vs. conclusively unsuccessful) are distinct, but noted they ultimately lead to the same path of assessing if remaining sources exist and if those remaining sources need to be addressed.

CPG made a comment about not remediating an area in a sensitive area, over a fiber optic cable, for example, and not including these areas in the sampling, SWAC estimate, and statistical evaluation. EPA replied this item is not part of this presentation but continued by noting these areas are part of the system, so they are meaningful and they should remain in the calculation of the SWAC. EPA also noted that including problematic areas in the IR footprint had been discussed and it was previously accepted that such areas would be part of the IR footprint and the implementing parties would take the necessary steps to remediate these areas.

In reply to a DEP question, EPA replied performance monitoring data will be reviewed during construction and at that time, if the data indicate issues, it would be expected that the parties would make an adjustment/correction to improve IR performance. CPG added that at the end of every dredge season CPG would look at data and make adjustments. CPG said they will make adjustments during the remedy in order to have a successful outcome. DEP wanted to ensure this is represented in the decision flow chart and EPA noted it is contained within the "Perform IR" block of the diagram.

CPG will review the presentation and reply to EPA by the next FS meeting. Also, today CPG submitted a file, *Weighting Lines of Evidence*, but it was not presented by CPG. EPA will review the file.

Approach to Balancing N and Y – CPG Presentation

CPG made the presentation *Approach to Setting Number of Samples and "Y" for Statistical Testing of IR* (see attached slide deck). This presentation was not on the agenda, but the participants agreed to see this presentation, which was prepared in reply to the EPA presentation on balancing sample size and Y made on April 16, 2020 at FS Meeting #27. In reply to an EPA question CPG replied that they did include a step of accounting for reduced concentrations in remediated areas. CPG explained they would scale up the concentrations in unremediated areas to achieve a SWAC of 85 and then determine the 95% UCL based on the resulting distributions . DEP noted they are interested in a low Y value and, in reply to a DEP question, CPG said Y could end up being identified as less than 1.5 in an instance where N = 400 sampling locations with 3-point composites. If Y is less than 1.5, 1.2 for example, then the selection would stop at Y = 1.2 and N = 400 sampling locations with 3-point composites.

EPA and DEP will consider this unscheduled presentation made by CPG and provide comments.

Assessing Potential Remaining Sources After IR - EPA presentation

EPA made the presentation *Identifying Remaining Sources in IR Completion Determination Framework* (see attached slide deck). A brief discussion followed and CPG said they will review the presentation file along with the Decision Tree presentation and reply to EPA.

Other Items

In response to an EPA question regarding DEP's reply to the EPA presentation made April 16, 2020 at FS Meeting #27 on Y, sample size, and error rates, DEP said they are raising the discussion to their management. DEP said there was a good exchange of information this week and they appreciated the presentation from CPG today.

EPA noted the revised IR FS is needed for the next CSTAG presentation. In response to an EPA question on schedule, CPG said they are targeting to submit revised Section 8 (Detailed Evaluation and

Comparative Analysis of Alternatives) of the IR FS on May 1, 2020. CPG also said they would need a response from DEP on Y, sample size, and error rates to finish the FS.

Next Meeting

The next meeting is FS Meeting #29 and it was set for April 30, 2020 from 10 am to 1 pm. EPA will send a meeting invite.

Action Items

EPA

- Send invite for FS Meeting #29 set for April 30, 2020 from 10 am to 1 pm.
- Review the CPG presentation made today (April 23, 2020) *Principles for Dredging Without Capping (Dredge-to-Clean)*.
- Review the CPG presentation made today (April 23, 2030) *Approach to Setting Number of Samples and "Y" for Statistical Testing of IR.*
- Review the CPG file *Weighting Lines of Evidence* that was submitted today (April 23, 2030), but not presented.

DEP

- Review the three EPA presentations made today (April 23, 2020): *Approach to Address Area Above River Mile 15; Proposed LOE Weighting Approach for IR Completion Evaluation Framework;* and *Identifying Remaining Sources in IR Completion Determination Framework.*
- Provide feedback on EPA presentation made April 16, 2020 on *Establishing Error Rates and Balancing Post-IR Sample Size and Y* and confirm agreement with information in presentation.
- Review the CPG presentation made today (April 23, 2030) *Approach to Setting Number of Samples and "Y" for Statistical Testing of IR.*

CPG

- Review and provide comments to EPA on meeting minutes: Conference Call (February 25, 2020); FS Meeting #24 (March 5, 2020), FS Meeting #25 (March 25, 2020), and FS Meeting #26 (April 2, 2020).
- Review the three EPA presentations made today (April 23,2020): *Approach to Address Area Above River Mile 15; Proposed LOE Weighting Approach for IR Completion Evaluation Framework;* and *Identifying Remaining Sources in IR Completion Determination Framework.*

FS Meeting #29
Conference Call
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
April 30, 2020

Agenda

- Remaining FS items/schedule
- Confirmation of Y and N
- Dredge to clean feedback
- LOE framework, remaining source and addressing above RM 15 feedback

Location: Conference Call

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner
- Keegan Roberts

CPG:
- Mike Barbara
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelsson
- Rob Law
- Bill Locke
- Hank Martin
- Bill Potter
- Doug Reid-Green

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- James Wands

DEP:
- Anthony Cinque
- Anne Hayton
- Jay Nickerson
- Myla Ramirez

USACE:
- Beth Franklin

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

Introduction

EPA welcomed the participants. EPA noted that the CPG had a very minor editorial comment on the meeting minutes from the February 25, 2020 FS conference call and these minutes are considered final. EPA and DEP noted they are both reviewing the CPG's suggested revisions to the meeting minutes from FS Meeting #24 (March 5, 2020) and FS Meeting #25 (March 25, 2020). DEP had previously provided suggested revisions to the minutes for FS Meeting #24, and the CPG provided their suggested revisions in the file containing the suggested revisions from DEP. DEP had previously indicated they did not have comments on the minutes from the February 25, 2020 FS conference call or FS Meeting #25. EPA noted that meeting minutes for FS Meeting #26 (April 2, 2020) and FS Meeting #27 (April 16, 2020) have also now been provided to DEP and the CPG for review.

Remaining FS items/schedule

EPA made the presentation *Specific Technical Issues under Consideration and Schedule Expectations - UPDATE* (see attached slide deck) to provide an update on the status of several specific IR FS-related technical tasks.

EPA indicated that three of the five topics on the "to be fully developed in the IR FS" list have been completed (the April 8, 2020 definition of source sediments is final, the CPG's probabilistic analysis of the impact of erosion on SWAC will be used in the IR FS, and the false positive error rate will be set at 10%), while the other two topics (addressing area above RM 15 and defining dredge to clean) are on today's agenda and not yet final. EPA indicated that both topics on the "to be developed to every extent possible in the IR FS" list (LOE weighting scheme, including balancing sample size and the Y factor, and defining remaining source/actionable remaining source) are on today's agenda and not yet final. EPA indicated that expectations have not changed regarding the topics on the "to be developed after the IR FS" list (pre-design sampling approach, geostatistical interpolation approach including uncertainty analysis, performance monitoring approach, and post-IR sediment sampling approach).

No comments were offered by DEP or the CPG on this summary.

Confirmation of Y and N

The CPG noted that they understand EPA's and DEP's concerns related to balancing sample size and Y, in that determining the sample size that corresponds to achieving the upper threshold of acceptable Y could prevent evaluating whether some relatively minimal amount of additional sampling would yield an appreciably lower Y factor.

EPA indicated that their position on post-IR sample size is that it should be between 400 and 800 sampling locations (with 3-point composites). EPA noted that they want to maintain the framework of constraints that would guide selection of sample size and Y, but not get into detail on the specific recipe that would derive sample size and Y until the PDI data are received because the PDI data will provide the information necessary to understand data variability and inform assumptions about post-IR conditions. The CPG indicated they understand the PDI data are important, but they would prefer to minimize the number of decisions left to design because each decision that is open-ended would make it more difficult to align parties to perform the IR. The CPG noted that the lack of specificity in the number of post-IR samples is just one of a number of uncertainties associated with the IR for which even if constrained in a reasonable range might still be problematic in bringing performing parties to the IR.

The CP proposed a revised approach to evaluating sample size and Y that would consider if a minimal amount of additional sampling would yield a substantial reduction in Y. In the new approach, the CPG would start with 400 sampling locations (with 3-point composites) and derive Y at the established false negative and false positive error rates. The CPG would then evaluate 50 additional sampling locations (with 3-point composites) and determine if that increase in sample size would yield a Y factor corresponding to a 20 ppt or more reduction in the false positive concentration threshold. The CPG noted that the equivalent evaluation for total PCBs would be if 50 additional sampling locations (with 3-point composites) would yield a Y factor corresponding to a 0.1 ppm or more reduction in the false positive concentration threshold. The CPG concluded that 50 additional sampling locations (with 3-point composites) would be added if this would significantly improve the Y factor, as defined by a 20 ppt or

more decrease for 2,3,7,8-TCDD or 0.1 ppm or more for total PCBs at the false positive concentration threshold.

EPA and DEP asked the CPG to further clarify how they would intend to scale the post-IR data based on the CPG's proposed approach from FS Meeting #28 on April 23, 2020. CPG replied that they would reduce concentrations in remediated areas and scale up the concentrations in unremediated areas to achieve a SWAC of 85 and then determine the 95% UCL based on the resulting distribution. EPA and DEP indicated they understood the CPG's response, but EPA suggested an alternate approach involving reducing the footprint to result in a SWAC of 85 ppt for 2,3,7,8-TCDD then sampling the resulting distribution to determine the Y and N relationship for the false positive test. A similar approach would be used for the false negative test. The CPG indicated they understood and would consider this alternate approach.

EPA indicated they do believe that what can be firmed up in the IR FS should be, assuming that firming up does not lead to extending the schedule for finalizing the IR FS. EPA and DEP indicated they appreciate the CPG's good faith effort to revise their proposed approach on balancing sample size and Y, and they will have to consider it. To facilitate this, the CPG noted they will develop a writeup of what was proposed today and provide it to EPA and DEP.

Dredge to clean feedback

EPA noted that they agree with several of the underlying dredge to clean principles as presented by the CPG during FS Meeting #28, but that EPA has proposed refinements to some of the underlying principles. EPA specifically noted that they agree with pursuing dredge to clean only within the extent of the footprint derived to meet the IR RAOs, that native material should be used to define clean, that the minimum area over which dredge to clean would be implemented should be 0.25 acres, and that factors such as constructability and safety would need to be evaluated in implementing dredge to clean. EPA asked the CPG to confirm that areas dredged to clean would still be backfilled with some cover like sand (but not an engineered cap), and the CPG confirmed that this is the expectation.

EPA suggested that restricting dredge to clean to when no more than 0.5 feet of deposited sediment occurs above native material appears premature, even in light of concerns expressed by the CPG for resuspension, additional processing and disposal, and slope stability. EPA indicated that they would prefer a more quantitative method for determining the depth to apply dredge to clean, and presented the concept of a cost-break-even analysis. EPA summarized that a cost-break-even analysis would evaluate the unit cost of dredging to a nominal depth followed by construction of an engineered cap compared to the unit cost of dredging to native material followed by covering with sand (including all related costs for material handling and disposal), and the depth of dredge to clean would be the depth where these costs are equal. EPA noted that a cost-break-even analysis was applied at the Fox River site.

EPA also suggested that with the application of a cost-break-even analysis, there would not be disincentive to apply dredge to clean in areas outside of nearshore areas, and therefore dredge to clean should be considered throughout the upper 9 miles according to the remaining dredge to clean principles.

DEP indicated that a cost-break-even analysis sounds preliminarily reasonable. In reply to a DEP question, EPA and the CPG confirmed that a 0.25-acre area would be represented by two PDI cores. The

CPG indicated that they have not thoroughly vetted the depth to which they would core during the PDI to find native material, but they did note that the deepest they would intend to evaluate chemistry is likely 3.5 feet. In response to an EPA comment, the CPG confirmed that PDI cores would extend deeper than 3.5 feet and that visual assessment of cores would be performed to evaluate the depth of native material.

The CPG commented that unit costs may be greater in deeper water or in particular portions of the river depending on specific characteristics, and that cost benefit may vary. EPA agreed that this would be possible, and that the cost-break-even analysis applied for the Fox River site did incorporate variability in unit costs for performing work in different conditions. The CPG suggested an approach might be to evaluate dredge to clean by dredge management unit, or even on a location by location basis. EPA agreed this could be a viable approach to applying dredge to clean principles with varying site conditions. To this end, the team discussed a screening tool that could be applied to select how deep to core during the PDI, to ensure that adequate information is available to fully consider dredge to clean. The CPG also suggested that the approach might still prioritize dredge to clean in nearshore areas. EPA agreed that dredge to clean would be beneficial in nearshore areas (to avoid placing an armor layer) but thought it could also be beneficial in deeper areas where indicated by a favorable cost analysis.

DEP noted that they appreciate the principles laid out including the revised principles brought by EPA. DEP indicated that they share EPA's concern that the default 0.5 foot limit for dredge to clean proposed initially by the CPG is potentially too restrictive. DEP asked how dredge to clean would work in practice, in terms of expected follow-up sampling and given there is likely to be an irregular native material surface. The CPG responded that there would be expected variability in the native material surface, but that a dredger would know they are hitting native material. The CPG acknowledged that all specific details of dredge to clean have not been thought through.

DEP concluded that the current dredge to clean principles including EPA's suggested revisions have merit, but DEP needs to discuss the overall approach as a team. The CPG concluded they will further discuss EPA's suggested revisions to the dredge to clean principles.

LOE framework, remaining source and addressing above RM 15 feedback

CPG presented an updated IR completion decision tree for discussion (see attached graphic). CPG proposed that if any concentrations above the RAL were observed in the post-IR dataset (in the remaining sources diamond), then they would consider the other information from earlier LOEs to determine if there are actionable sources. The CPG suggested that evaluating IR implementation should include assessing the data from before the IR to determine if actionable sources are present. EPA asked how PDI data would be used to assess if something had been missed by the IR, when the IR footprint will be based on the PDI data. The CPG provided an example where if post-IR sample concentrations were elevated, the PDI data could be assessed to determine if the confirmatory samples were collected at the edge of where a footprint boundary was drawn during design. EPA indicated that information collected prior to the IR should be contextual in nature, and that this information should not be given weight in the post-IR time and used to determine that the IR is complete simply because an action was performed based on an approved mapping and design. CPG agreed that the pre-IR information would be contextual but that all available information should be used to inform decisions. EPA agreed with the concept of using all available information to inform decisions, but reiterated that pre-IR information should not in and of itself determine whether the existence of concentrations above the RAL are meaningful and that

a separate definition for remaining source and actionable remaining source has been developed by EPA for discussion.

DEP concluded that the revised IR completion decision tree appears reasonable to move forward with, and that using all available information is appropriate to inform diagnostics. DEP called out one specific issue, that the LCL diamond should specify "RAO 1 Goal" and not "Y * RAO 1 Goal". The CPG agreed this is incorrect and would be modified. EPA concluded that the revised decision tree should be used, but that the CPG should ensure that the narrative of Appendix H matches the decision tree including appropriately describing the nature of considering pre-IR data in the post-IR timeframe.

The CPG presented a list of questions about EPA's most recent proposal on incorporating the area above RM 15 into the IR RAOs (see attached slide). EPA confirmed that a concentration above the 2,3,7,8-TCDD RAL or total PCB RAL (1 ppm) and representing an impact to recovery would be a candidate for remediation, and it would be treated the way it is treated below RM 15 (including considering feasibility of remediation). EPA indicated that it would be their expectation that an identified source above RM 15 would be incorporated into the post-IR SWAC whether remediated or not. EPA also confirmed that if an area above RM 15 were remediated, it could offset area below RM 15 that would then not need to be remediated.

The CPG asked if incorporating a discrete source area above RM 15 would corrupt the SWAC from RM 8.3 to RM 15. The CPG pointed out an example where 2 acres of 2,3,7,8-TCDD at 300 ppt above RM 15 would be equivalent to 4 acres of 150 ppt below RM 15. The CPG also pointed out an analogous example for total PCBs, where 2 acres at 2 ppm would be equivalent to 8 acres at 0.5 ppm below RM 15. The CPG concluded that the credit of remediating a source area above RM 15 is not worth the potential consequence of not remediating such an area. The CPG further noted that they believe EPA's approach to incorporating sources above RM 15 (by incorporating such sources in the post-IR SWAC calculation whether remediated or not) constitutes two distinct ways of addressing source, and questioned whether it was CSTAG's intent to treat the area above RM 15 differently than the area between RM 8.3 and RM 15. EPA responded that they do not believe this was CSTAG's intent, and that EPA does not view the proposal as two separate ways of addressing source.

DEP noted that they believe the last footnote provided by EPA (FS Meeting #28) appeared to be a fair approach to incorporating potential sources above RM 15, and that the last footnote provided by EPA is consistent with a final remedy. The only question DEP had on the last footnote from EPA was in the first sentence, should "…data collected between RM 15 and Dundee Dam prior to the IR design…" instead read "…data collected…during the IR design…" or "…data collected…prior to IR construction…".

EPA and DEP indicated they would need to evaluate the issues identified by the CPG. The CPG indicated they would further consider the option that was the original EPA proposal (FS Meeting #26) that concentrations observed in the area above RM 15 in excess of RALs developed for the stretch from RM 8.3 to RM15 would be considered sources during the IR.

The team discussed having the next FS meeting on May 7, 2020 from 1030am to 130pm.

EPA requested that the CPG indicate the priority of remaining decisions needed to move forward with the next version of the IR FS. The CPG indicated they need resolution in this order: incorporating the area above RM 15; then dredge to clean; then balancing N and Y.

Action Items

EPA

- Set up FS Meeting #30 for May 7, 2020 from 10:30-1:30 with agenda and working meeting platform.
- Review the description of the proposed revised method to determine N and Y (description forthcoming from the CPG).
- Review CPG's input on FS Meeting Minutes for #24 and #25.
- Further consider the issue of addressing potential sources above RM 15.

NJDEP

- Review the description of the proposed revised method to determine N and Y (description forthcoming from the CPG).
- Review the proposed revisions to the principles of dredge to clean presented by EPA on the call today.
- Further consider the issue of addressing potential sources above RM 15.
- Review and provide comments to EPA on minutes for FS Meeting #26 and FS Meeting #27.

CPG

- Submit a description of the proposed revised method to determine N and Y as presented on the call today.
- Review the proposed revisions to the principles of dredge to clean presented by EPA on the call today.
- Further consider the issue of addressing potential sources above RM 15, including feedback provided by EPA and DEP.
- Review and provide comments to EPA on minutes for FS Meeting #26 and FS Meeting #27.

FS Meeting #30
Conference Call
Meeting Minutes
Lower Passaic River Study Area Interim Remedy Feasibility Study
May 7, 2020

Agenda

- Remaining FS items/schedule
- Y and N feedback to CPG
- Dredge to clean feedback to EPA
- Footnote addressing above RM 15

Location: Conference Call

Participants:

CDM Smith:
- Andrew Bullard
- Aaron Frantz
- Scott Kirchner
- Keegan Roberts

CPG:
- Mike Barbara
- Jennifer Benaman
- John Connolly
- Gary Fisher
- Marcia Greenblatt
- Sue Harden
- Tal Ijaz
- Peter Israelsson
- Rob Law
- Bill Locke
- Bill Potter
- Doug Reid-Green

EPA:
- Diane Salkie
- Michael Sivak

HDR:
- Ed Garland
- James Wands

DEP:
- Anthony Cinque
- Anne Hayton
- Jay Nickerson

USACE:
- No representative

OTHER:
- John Kern (Kern Statistical Services)
- John Wolfe (Limnotech)

Remaining FS items/schedule

LOE weighting framework - In response to a DEP question on the factors to be considered for determining remaining source, CPG replied if concentrations are detected above the RAL, then the sediment is classified as remaining source and an assessment is performed to determine if the source is actionable. Participants reviewed the decision flowchart presented at FS Meeting #29 on April 30, 2020. DEP requested an "Evaluate IR Implementation" step in the flowchart if no remaining sources are identified. After some discussion with participants and confirmation that supporting narrative in Appendix H of the IR FS expands on the evaluation of IR implementation, DEP agreed that the flowchart from FS Meeting #29 on April 30, 2020 is acceptable, and the narrative should support the flowchart.

Defining remaining source/actionable remaining source – These items were shown to the participants and were noted to have been previously presented by EPA in FS Meeting #28. In response to an EPA question, DEP and CPG agreed to the principles/items *for defining remaining source/actionable remaining source* and incorporating them into Appendix H of the IR FS.

RAO 1 footnote addressing above RM15 feedback

The May 6, 2020 version, which contained EPA suggestions, of the RAO 1 footnote was reviewed. The DEP and CPG agreed to removing the time reference ("during the IR" and "prior to the IR" were time terms considered in the sentence) of sediment data collection in the second sentence of the footnote so that the sentence reads "However, if sediment data collected between RM 15 and Dundee Dam that support IR design…".

In response to an EPA question on the CPG's use of "in conjunction with", CPG replied that if an action is necessary above RM 15 to Dundee Dam, their intent is to perform that action during the IR, their intent was not to perform it separately from the IR. The CPG further explained RAO 1 applies to RM 8.3 to 15, the SWAC goal is for RM 8.3 to 15, but an action above RM 15 is not part of meeting RAO 1 or the SWAC goal. Therefore, the intent was to have language that would separate RM 15 to Dundee Dam from RAO 1 and the SWAC calculation, but action above RM 15 would be done during the IR. A few minor edits were reviewed on the call and the DEP and CPG agreed to the footnote language. EPA will present this edited footnote to their regional counsel for review.

Dredge to clean feedback to EPA

CPG presented the *Draft Proposed Dredging without Capping Principles* dated May 6, 2020 (see attached). The principles were discussed and EPA provided two comments 1) a minimum coring depth should be set in Step 1, based on the depth needed for the standard engineered cap and 2) additional depth should be added to the coring depths identified in Step 1 so that if greater dredge to clean depths are identified in Steps 4 and 5, then the correct core information is available for assessment in RD/RA. CPG agreed to the logic of the comments and agreed to make the edits for the language to be added to the IR FS.

DEP agreed with the EPA comments and asked if the principles meet the intent of dredge to clean without interfering with a final remedy and EPA said the dredge to clean suggestions are consistent with a final remedy. Consistent with EPA's prior recommendation, the CPG proposal is a method to identify the breakeven cost between dredging to clean versus dredging and capping. DEP also noted they are interested in having permanence included in the evaluation, not just cost. DEP will review the principles and provide comments to EPA and the CPG early in the week of May 11, 2020.

Y and N feedback to CPG

The participants discussed the CPG's Proposal to Amend the Desktop Analysis that Establishes the Number of Sampling Locations in the Post-IR Sediment Sampling Program dated May 6, 2020 (see attached). DEP commented that their issue is the 20 ng/kg and 0.1 mg/kg metrics for TCDD and PCB, respectively, because the method with these metrics excludes the sample size from increasing beyond 450. DEP agreed that this 450-sample size limit is only applicable if Y = 1.5 at N = 400. DEP said if Y can be reduced from 1.5 to 1.25 by doubling the sampling size (i.e., 400 to 800), the change is worthwhile to DEP. DEP suggested moving to increments of 5 ng/kg TCDD and stated they believe an acceptable

minimum Y would be 1.2. DEP suggested another potential approach could be to calculate the difference in Y with 400 locations and 800 locations and continue adding increments of 50 samples as long as the reduction in Y is more than one-eighth of this difference.

CPG replied that more samples mean more time and cost, so higher N should be acceptable only if it makes a material difference. EPA noted the post remedy sampling program would not be as large as the PDI sampling program.

The CPG noted that in communicating the success of the interim remedy, it will be easier for the public to understand that all sediment above the RAL was removed, rather than the confidence limit on the mean was below Y times 85ppt.

DEP said they will discuss the CPG's Y and N proposal and respond to EPA and the CPG.

Next meeting

Participants agreed that a meeting does not need to be set at this time. No meeting was scheduled.

Action Items

EPA

- Request feedback from EPA regional counsel on the edited footnote to RAO 1.

DEP

- Provide feedback to EPA and the CPG on the CPG's *Draft Proposed Dredging without Capping Principles* early the week of May 11, 2020.
- Provide feedback to EPA and the CPG on the CPG's Proposal to Amend the Desktop Analysis that Establishes the Number of Sampling Locations in the Post-IR Sediment Sampling Program.

CPG

- No action items specified.